PRODUCT
ENGINEERING

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It's Fun to Paddle in Shallow Waters

WHAT differentiates successful engineers from countless others who are just engineers? Is it personality, exceptional knowledge, hard work, or just plain luck? One answer to this question can be found in an address given by Professor R. E. Doherty, dean of the Yale School of Engineering. Speaking before a meeting of the New England Section of the Society for the Promotion of Engineering Education, he described the "usual engineering graduate" as follows:

"In learning from others how to do a routine job—for example, the calculation of stresses or densities—he is usually very apt; in college he became proficient in making such slide-rule calculations from formulas. But when a problem confronts him for which there is no formula, what happens? A river to swim, and he can't swim. His muscles may be strong, but they are undisciplined and unpracticed at swimming. He paddles around in shallow water looking for shoals, which are not there, to hold him up in crossing. As the time approaches when he is expected to be on the other side, he is seized with emotions which are dark and despairing. Finally he sees a way; he goes across on somebody's back. It works out all right this time, he thinks; the ride is interesting and also similar to many he experienced at college, so he now knows how to get across next time. Thus he comes to the habit of remaining in shallow water . . ."

THIS is by no means a sweeping condemnation of the engineering profession. It applies specifically to the young engineering graduates only a few years out of college. In the school of bitter experiences and hard knocks, many of them give up their attempt to enter the engineering profession and drift into more congenial occupations ranging from tea-room proprietors to bond salesmen. The profession is thus automatically rid of many of the misfits.

Quoting the same address, there are "too many engineering technicians and too few creative thinkers." And therein lies the explanation for many of the cases of engineers who have failed to succeed in spite of the fact that they were expert in the handling of theories and formulas.

Facts and formulas and their manipulation are taught well in our engineering schools. But their application to the solution of a comprehensive engineering problem is something that cannot be done by rules. That can be done only through a complete engineering analysis and original thinking. What is the product to accomplish or what purpose is it to serve; what are the various means by which the desired results can be obtained; what loads and forces are to be resisted; what service conditions must be met; what must be the physical properties of the materials to be selected; what materials are available; what manufacturing processes will be most economical; what commercial standard parts can be used to advantage; what can be done to enhance the appearance and improve the salability of the product? These and dozens of other questions, most of them overlapping, must be answered without formulas or rules.

NEVER before have there been so many new materials and processes waiting for product designers to apply them. To him who paddles in the shallow water, they appear as things better ignored, things beyond his depth—only to be reached by riding the back of a strong swimmer. But these new developments are challenges to spirited battles with unknown factors, adventures in new discoveries out where the water is deep and the fish are big, a chance to make a brilliant success. The world pays homage to those who show the way—the creators of the new.

Engineering

Recognized authorities summarize the facts and fundamental principles that must be studied —

Scope and Limitations of Processes
Materials Available
Specifications for Welded Products
Stresses and Deflections
Concentrated Stresses
Fatigue Failure
Vibrations Damping
Appearance

BACK in the period when fusion welding was being introduced, cost and lightness were emphasized almost to the exclusion of every other factor. Those interested in fostering welded construction took great pride and delight in demonstrating how it was possible to manufacture a relatively complicated machine part with not much more shop equipment than a drill press and a welding outfit. Such products were often crude and usually unattractive. They could hardly be classed as designs because little or no fundamental engineering was applied. These were the embryos from which grew the most radically different method of product manufacture that the world has ever witnessed. And of greater importance to the designing engineer is the fact that welding, now perfected as a manufacturing process, presents a new field for the exercise of his skill and ingenuity.

Early designs of welded parts were simple elements, relatively small. They were confined to supporting brackets, pedestals and similar machine parts that were subjected to static loads only. Hence, cost and weight were the predominating factors. Furthermore, in the beginning designers did not have complete confidence in the welding process, and its technique and control had not been developed to their present high state.

Hand in hand with the tremendous progress that was made in the art of welding during the past decade was the refinement of the flame-cutting process. More recently, there has been added the process of flame-machining. As these arts progressed, engineers grew more confident and gradually undertook the design of bigger and more complicated welded constructions. Commercial "welderies" that made a specialty of welding were established. Experts of recognized ability were put in charge. Such plants adopted the most highly developed technique and control and employed only highly skilled welders whose work was subjected at all times to rigid inspection and tests. Today, welded parts or products from such welderies are of a uniformly high quality. No longer is the engineer restricted in his design by the scope and quality of welding that his company's shop may be equipped to handle.

How has the designing engineer kept pace with the rapid development of fusion welding? Imitation is a strong animal instinct, and in many of the early welded constructions we see nature asserting itself. Even today we sometimes see examples of rolled plates and structural members welded together to imitate castings.

As is always the case, in the course of time leaders came forward. Theories were builded on the facts of experience. Laboratory tests and research supplied the data. Logical thinking replaced random effort. Thus was evolved a technology for the design of welded products. It is not to be inferred that this field of product design in any way departs from established engineering principles. To the contrary, the fact should be emphasized that in designing for this method of construction a complete engineering analysis must be made. Restrictions and requirements of other methods of construction that do not apply to this form of fabrication must be recognized. At the same time, the designer must take into consideration new factors that might be involved as a result of the differences in the materials and in the method of joining the members.

Rolled Steel for the Welded Product

H. G. MARSH

Chairman, Trade Research Committee, Carnegie Steel Company

IN DESIGNING heavy machine parts to be made of rolled steel, the forms and sizes in which shapes, plates or forgings are commercially obtainable frequently dictate the general character of the design. It is impossible to state specifically the maximum sizes in which such material can be furnished by the steel industry. There are so many factors involved when dealing with extreme sizes, both large and small, that each

the Design of Welded Products

inquiry is a problem in itself and must be so considered. It should be understood that in the case of every steel mill the acceptance of orders for material near the upper limits of size would be subject to conditions existing at that time. For this and other reasons it is extremely desirable that the engineer should take up his raw material problem with the steel mill before the design has been developed too far.

In every steel plant, its machinery and equipment place definite limits on the sizes that can be rolled or forged. Therefore any statement concerning maximum available sizes of steel plates and shapes must be considered as a generalization, and it is necessary to confine any discussion of this subject to the products of a specific steel plant. The data given here refer to the output of the Carnegie Steel Company. However, as the mills of this company are capable of turning out approximately the largest sizes of plates, shapes and forgings generally obtainable, the figures given here can be considered as typical for the general industry.

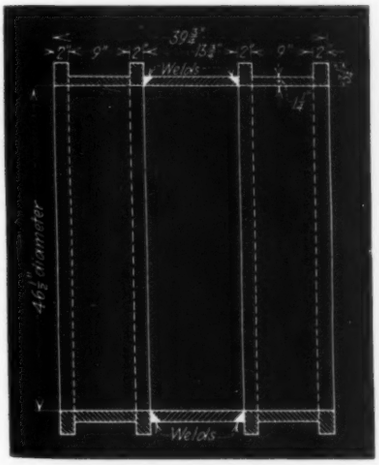
Forged Plates

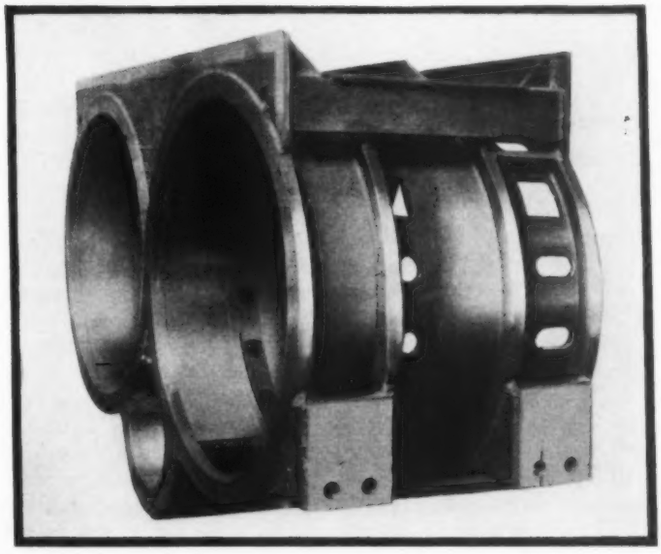
The published range of sizes as given by the Carnegie Steel Company for commercial forged plates is 72 in. maximum in width, 12 in. maximum in thickness and 20 ft. maximum in length. These dimensions are limited by space and handling equipment but, regardless of dimensions, the weight limit is 70,000 lb. It must be emphasized that these are the limitations of the published range of sizes, this range covering most of the commercial requirements.

Published sizes do not always indicate the actual limits. Thus, in another department there is equipment for special purposes which enables us to forge plates up to 150 in. in width, 20 in. in thickness, and 150,000 lb. in weight. The maximum length would be 35 ft., and for that length the thickness of the plate would have to be at least 3 in. in order that the plate can be handled without buckling or bending. It can readily be understood that it would be practically impossible to publish a definite range of sizes for plates of this character.

As a specific illustration of the impossibility of establishing definite size limits for forgings, the 20-in. thickness referred to in the above paragraph is not really a maximum for all sizes. Thickness depends in some cases upon the amount of reduction of the original ingot that may be required for the particular purpose for which the plate is to be used. United States Navy specifications call for a reduction of 3 to 1 for the main body of crankshafts, but permit a 1.7 to 1 reduction for large flanges on the shaft. It is reasonable to assume that for most machine parts a reduction of 1.5 to 1 or 1.7 to 1 would be sufficient.

In our mills the thickness of the original ingot is about 36 in., this representing the smallest dimension of the largest ingot mold used. Allowing for discard, this would produce a piece about 150,000 lb. in weight. There is also a possibility of sand casting even larger ingots. However,





Each "barrel" of this motor frame for electric locomotives is built up of two special rolled channels with a 13¾ x 1¼ in. plate between. Each piece is circled, and the three rings are then welded as shown

a weight of 150,000 lb. and a width of 150 in. will cover most requirements and give engineers a sufficient latitude in their design.

Rolled Plates

For rolled plates the size range is more definitely established and is published by the various steel manufacturers. In our own case we roll commercial plates up to 146 in. in width and 15 in. in thickness, with a weight limit of about 30,000 lb. Here again the various steel mills are usually capable of exceeding these figures to a limited extent, but any inquiry for material beyond these figures would have to be given special consideration.

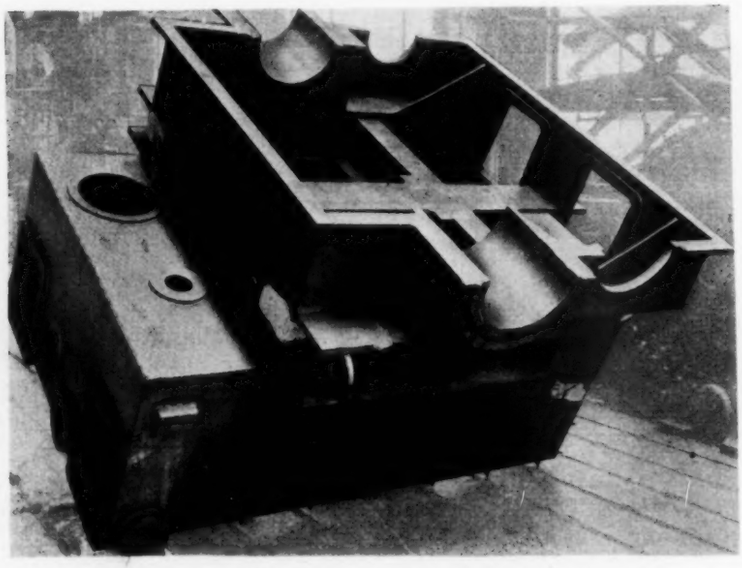
Structural Shapes

Designing engineers can gain much by thoroughly familiarizing themselves with the products of the various steel manufacturers and taking advantage of the great variety of rolled sections available. Often economies and improvements in design can be accomplished by incorporating in the machine construction some one or several of the standard or special rolled shapes available.

Undoubtedly the time will come when special rolled sections will be the solution of some construction problems. This would apply where there are a great many parts of the same kind or where a given section can be made to serve for several purposes. Although the roll cost for special sections is rather high, if sufficient tonnage is involved the unit cost becomes relatively small and might be more than offset by advantages gained through the use of the section.

The line drawing and picture of the motor frame of the new electric locomotives for the Pennsylvania Railroad is an excellent example of the application of special rolled sections. The special channels used for this design were rolled for the purpose by one of the large steel companies, and this, I believe, is the first time a special section was rolled for machine construction. Recent inquiries indicate that designers are giving a great deal of thought to the possibility of using special rolled sections to advantage.

Occasionally the question comes up as to the relative economy of structural rolled shapes versus sections built up by welding together plates. As structural rolled shapes and plates are generally sold on the same price basis, there is ordinarily no economy in substituting a built-up welded section for a rolled section. But there are some conditions where built-up shapes are cheaper or structurally better than the equivalent rolled section. If the rolled section must be formed or circled, it is sometimes cheaper to build up the section from plates. Similarly, where the section does not conform to dimensional requirements, as for example in a beam with one flange thicker than the other, it may be more economical to develop the desired construction through the use of welded plates. Usually it is more economical to use rolled sections.



Well-executed designs take the greatest possible advantage of available materials. Plates, structural shapes, pipes and checkered floor plates are here welded together to make a gear reduction housing. Note how the "window frames" have been rounded at the corners

Alloy Steel

Because the various alloy steels have not been used to a great extent in machine construction, their possibilities in this line are more or less undeveloped. Rigidity is usually the important factor in machine construction and not the tensile strength or elastic limit of the steel. For a given construction, rigidity is determined by the modulus of elasticity, the value of which is practically the same for all steels. Therefore, where weight, strength and resistance to wear or fatigue do not enter into the problem as a major factor, plain carbon steel should be used.

In the past year great strides have been made in some of the simpler alloy steels. It appears that the trend is toward simpler steels and simpler heat-treatment, with special attention given to the control of grain structure, and steel manufacturers are beginning to make steel for the particular purposes for which it is to be used rather than to definite standardized specifications. It is becoming more generally recognized that grain structure is equally as important as chemical composition, even in the as-rolled condition of the steel.

Scrap Losses

Practically all steel manufacturers are equipped to flame-cut, and where the buyer will have no use for the scrap it is far cheaper to have the flame-cutting done at the steel mill. In this case, the buyer is allowed a scrap price for the waste material and, furthermore, he saves on the freight. On the other hand, where the scrap is of such size and shape that it can be used for other construction, it will be cheaper for the buyer to take all the material, do his own flame-cutting and utilize the scrap. This pictures the general situation. The steel mills cannot be expected to allow more than scrap price for the discarded material as they will have no use for it other than re-melting it. The only exception to this rule would

be where the scrap is of sufficient size and proper shape to be suitable for re-rolling. A slab price is sometimes allowed under such conditions.

By a careful study of the problem, the designer is often able to select shapes and sizes that will leave only a small amount of scrap. This can sometimes be done by ordering a plate large enough so that a number of pieces can be cut from it. Like everything else, this procedure can be carried to excess as there are extra charges for the wider plates.

Flame-Cutting and Gas Welding

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ONE of the most far-reaching developments in the field of manufacturing processes has been that of flame cutting by means of the oxy-acetylene blowpipe. Plates thicker than about $\frac{3}{4}$ in. cannot be sheared mechanically without damaging them. Machine cutting, as with a planer or milling machine, is relatively expensive. If the profile is to be an irregular curve, the cost of cutting it by machine tools becomes prohibitive. Therefore, up until the commercial perfection of the flame-cutting process, heavy plates and thick slabs could not be used economically for machine parts.

All thicknesses of steel slabs employed for machine frames and similar parts are being flame-cut without difficulty. The accuracy of the cut will vary with the thickness of the plate, as shown in the accompanying table. The width of the cut will vary from $\frac{1}{16}$ in. to $\frac{1}{2}$ in. according to the thickness of the plate.

The tolerances given in the accompanying table can safely be specified and are well within the commercial limits. Indeed, in particular cases the variation has been held to plus or minus 0.002 in. in cutting plates 2 in. thick. As to uniformity and squareness of cut, with machine flame-cutting this can be held within a few thousandths for squareness of cut and uniformity for all thicknesses up to 2 in. It will be noticed that these figures compare quite favorably with the accuracy ordinarily obtained in rough machining. The surface finish of the cut face of the plate or slab will usually be sufficiently smooth in appearance.

Tolerances for Oxy-Acetylene Line Cutting

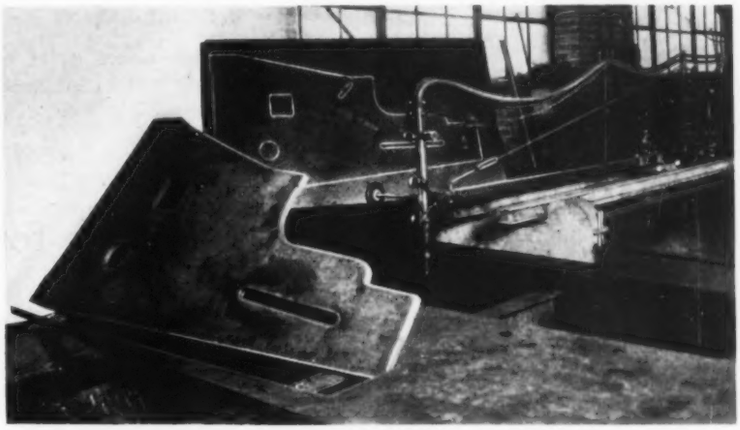
Depth of Cut or Thickness of Plate	Minimum Tolerance
2 in.	± 0.0100 in.
6 in.	± 0.0312 in.
12 in.	± 0.0625 in.
24 in.	± 0.1250 in.

Practically all the steels commonly used in industry can be flame-cut cold without any damage whatever to the physical and chemical characteristics of the steel. Steels having carbon contents above 0.35 per cent should be preheated before cutting and normalized afterwards.

At various times it has been claimed that flame-cutting damages the metal adjacent to the cut. It is true that when cutting the higher carbon steels a hard surface is left by the cut. But this is prevented by the preheating and normalizing. If the proper procedure is followed there will be no impairment of either the physical or chemical characteristics of the steel. This has been proved by extensive tests conducted in Germany, the results of which have thus far been substantiated by researches that are being conducted by the American Bureau of Welding in cooperation with the American Society of Civil Engineers and others.

Flame Machining

Although flame machining cannot as yet be considered as a commercial process indications are that it is something with which the designer should keep in touch. Fundamentally, it is a flame-cutting process analogous to machine planing and turning operations, the oxygen steam being used in place of the cutting tool. Rough surface planing can be done in this manner to within $\frac{1}{8}$ in. to $\frac{1}{4}$ in. of the desired finish dimensions. One practical application is in the preparation of edges for butt welding. The plain square-edged plates are simply butted and a U-shaped groove is then flame-cut along the joints. Another application which is developing quite rapidly is that of breaking corner edges. Such edges can be made rounded, flat-beveled or even concave. In this same class of new applications of the cutting blowpipe is flame-borning. It is still entirely in the experimental stage. It is mentioned here as another one of those possible forthcoming new manufacturing processes of which the designer should be ready to take advantage.



By specifying flame-cutting, parts can be designed as one piece to give best stress distribution and appearance

Weldable Materials

Although practically all of the ferrous metals, including the alloy steels, and most of the non-ferrous metals can be welded, it must be pointed out

Classification of Chromium Steel Alloys

	Per Cent *C*	Per Cent *Cr*	Per Cent *Si*	Per Cent *Ni*
Group I	Over 0.20	12-16	.....	.....
Group II	Less than 0.12	12-15	.....	.....
Group III	Less than 0.12	16-20	0.50-1.50	.....
Group IV	.....	17-25	.....	7-12
Group V	.....	7-25	.....	17-22
Group VI	Less than 0.3	20-30	.....	.....

that some of these offer considerable difficulties, and in some instances the welding would not be satisfactory for all conditions of service, such as shock loads. Therefore, the designer should make every effort to use those materials that will present the least difficulty in making welded joints of the desired strength and ductility.

As a general statement the lower the carbon content of the steel the easier it will be to get the weld metal to have the same strength and ductility as the parent metal. A sub-committee of Committee A-1 of the American Society for Testing Materials adopted a list of steel specifications that in the opinion of that committee are especially satisfactory for fusion welding either by the gas or electric arc process. This list can well be used as a guide.

Successful methods have been developed for welding nickel-clad and stainless-clad steels. With the proper welding technique, the valuable corrosion-resisting qualities of the nickel or stainless steel clad are preserved, there being no appreciable amount of alloying with the low carbon base metal.

With reference to the welding quality of the stainless and heat-resisting alloys, through the proper procedure control all of these alloys can be welded without seriously handicapping the properties of the metal. Some of them require a considerably different treatment. In the tabulation above the chromium and chrome nickel alloys have been divided into six groups to indicate the different procedures that must be followed.

Although all of these alloys can be welded the straight chromium alloys falling in Groups I, II and III require a special treatment. The weld must be heat-treated to remove the brittleness. However, most of the stainless steels fall in Group IV. Stainless steels in this classification do not air-harden. Both the weld metal and the base metal are ductile after welding.

Special bronze welding rods are extensively used for the bronze-welding of cast iron and malleable iron. However, where rigidity and the ability to withstand heat stresses are desired, the regular cast iron fusion welding is still preferred.

Copper or brass tubing can readily be welded to cast iron, steel, malleable cast iron, bronze, brass and other copper alloys. This construction is widely used in heat exchangers, heaters and similar devices. The welding rod used is usually bronze, although silver solder is sometimes used.

Wearing Surfaces

Designers can effect great economies by making use of some special material having high wear-resisting qualities and coating this material on the parent metal. Haynes Stellite is commonly used. A new type of hard-facing welding rod consists of particles of crushed tungsten-carbide embedded in a suitable binder which may be high-strength steel, Hascrome or Haynes Stellite, depending upon the type of application. A layer of this material gives a surface of extremely hard particles embedded in a tough base metal. It is for wearing surfaces subjected to most severe abrasion, such as the first two or three flights of a screw conveyor handling ashes. The balance of the flights would probably be Haynes Stellite.

Closely analogous to hard-surfacing is the surfacing with bronze or any other desired material. Pistons and other reciprocating parts of engines, pumps and other machinery have been surfaced with bronze and then machined to the desired finish. Manganese bronze is usually used for this purpose as a softer bronze has a tendency to draw and pinch the piston rings. Surfaces can be coated in a similar manner with corrosion-resisting materials for specific services. A construction that is used commonly.

Designing for Automatic Welding

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WHERE there is uniformity of production, automatic arc welding demands consideration. By uniformity is meant not only a given size and shape of an article, but also uniformity of location of welds, so that standard methods of assembly can be used. It is, of course, necessary to have a sufficient amount of production so that the quantities involved will be such as to permit savings over present, accepted or contemplated methods. The savings must justify the required capital investment. It is a question of cost and cost reduction. Wherever applicable, automatic welding is an accepted, recognized commercial method of fabrication.

There are two general methods of automatic arc welding, the carbon arc and the metallic arc. The process by which the welding is done may be classified as shielded arc and bare or non-shielded arc.

With the shielded arc the weld metal deposited has the qualities demanded by present-day designs. It has high tensile strength, is shock and fatigue resisting, corrosion-resisting and—of vital importance—it is ductile.

The process selected depends upon the plate thickness and various assembly factors. The shielded carbon arc is used up to approximately $\frac{3}{4}$-in. plate and the shielded metallic

TABLE I

General Purpose Steel for Arc Welding

	Analysis	Per Cent Limits
Carbon	0.20	0.15 to 0.25
Manganese	0.45	0.35 to 0.60
Silicon	0.04	0.07 max.
Sulphur	....	0.05 max.
Phosphorous	....	0.045 max.
Aluminum	None added	Not more than 2 oz. per ton added to steel

above that. No hard and fast rule can be set down as so much depends on the specific conditions involved. It is a question of cost.

Having cost in mind, the designer must first consider volume of production. There must be sufficient volume to warrant further investigation. This statement may seem exceedingly elementary, but it is surprising how many times investigations are made which are of no use because the amount of saving is not enough, because of low value of volume, although the percentage saved may be high.

Second, welds or suggested welds or joints in the design must be classified. It is not necessary that the parts be exactly alike—they may be similar—jigs, fixtures may be of the combination type thus permitting a good volume of production to go through the welding department; welds may be repeat welds but need not be on the same part or parts.

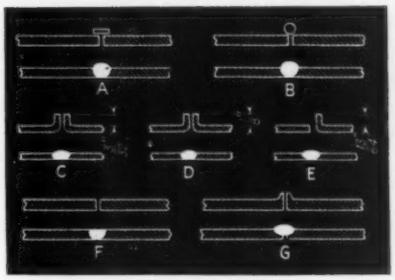
TABLE II

Deep Drawing Steel for Arc Welding

	Analysis	Per Cent Limits
Carbon	*	0.07 to 0.15
Manganese	0.40	0.35 to 0.55
Silicon	....	0.05 max.
Sulphur	....	0.05 max.
Phosphorous	....	0.045 max.
Aluminum	None added	Not more than 2 oz. per ton added to steel

* (as high as practical)

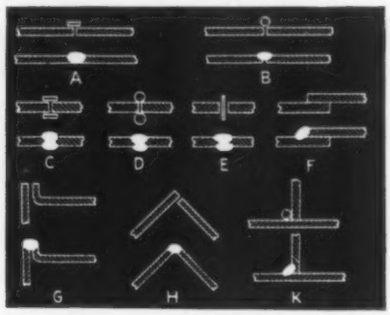
Classes of Welds for Automatic Arc Welding



A and *B*, filler metal added, work clamped in position on copper backing. Welding speed 130 ft. per hr. on thin gages to 45 ft. per hr. on $\frac{3}{16}$-in. thickness

C, *D* and *E* for 16- and 18-gage sheets, two edges turned up. On 14-gage, one edge is turned up as at *E*

F and *G*, seams are clamped tightly together without backing, average penetration 70 per cent



A and *B*, filler metal added, seams clamped, no backing, average penetration 70 per cent. Welding speed 55 to 260 ft. per hr. for thicknesses from $\frac{1}{8}$-in. plates to 14-gage sheets *C*, *D* and *E*, filler metal added, welding from both sides, no backing. Welding speed 10 to 50 ft. per hr. on plates $\frac{1}{4}$-in. to $\frac{1}{4}$-in. thickness

F, work clamped or tacked in place, no backing. Welding speed 150 to 40 ft. per hr. for thicknesses from 18-gage sheets to $\frac{1}{8}$-in. plates *G*, edge weld, welding speed from 250 to 135 ft. per hr., for thickness from 20-gage sheets to $\frac{1}{4}$-in. plates

H, corner weld, work clamped in position on copper backing. Welding speed from 130 to 90 ft. per hr., for thicknesses from 18-gage sheets to $\frac{3}{16}$-in. plates

K, fillet weld, filler metal added, seams clamped or tacked, no backing. Welding speed 40 to 60 ft. per hr. for plates ranging from $\frac{1}{4}$ in. to $\frac{5}{16}$ in. in thickness

Considering the operation of the shielded carbon arc in welding steel, it is necessary that good welding steel be used. For pipe, tanks, tubes, shapes, and similar parts that do not require a large amount of cold forming, the analysis of steel as given in Table I is recommended.

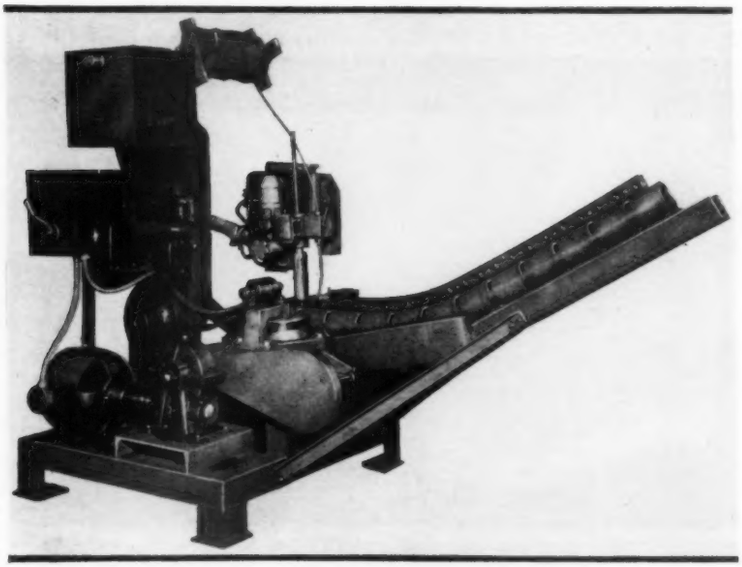
This general-purpose steel is the best suited for arc welding at high speeds and therefore should be used in all cases where physical requirements permit.

For steel for deep drawing or for considerable cold forming or soft sheet steel, the analysis given in Table II is recommended. The maximum welding speed for this grade of steel will generally be less than that of the higher carbon general-purpose steel. In some cases physical requirements for the steel plate or sheet such as hardness, high tensile strength, deep drawing qualities may require narrower limits than those specified above.

For convenience, various types of welds are divided into the classifications shown in the accompanying sketches, and explained in the captions. It is to be noted that the shielded carbon arc process requires a minimum of preparation of parts for welding. The abutting edges must be reasonably close together, clean and suitably lined up. In the metallic arc process, a certain amount of preparation may be needed, such as scarfing, which in some cases involves machining.

The assembly problem must also be considered—whether two or three sub-assemblies are to be used, and what effect this will have on the accuracy of final assembly.

The location of welds must be studied in reference to the individual piece and in reference to all pieces and all assemblies—having in mind the standardization of items and parts. Joint details and the placing of joints must be worked out. The



Starter frames designed to be automatically arc welded. A continuous stream of finished frames is delivered

welds must all be easy to reach.

After the assembly has been made further treatment may be needed. First comes the question of heat-treatment, and from that on down to painting. Depending upon the parts involved, the effect of each item on the final assembly and cost and process must be considered.

A suggested scheme of cost calculation is as follows: For given conditions, power at the arc is known. The kw. input may be calculated from the efficiency, and from this input and the power rate the cost of power. Account must be taken of set-up time and fatigue. Knowing the arc conditions for a given set-up the cost of electrode used can be calculated. Autogenizer needed or other additional fluxes can be estimated from tables of manufacturers. Labor is figured on the basis of one hour, at prevailing rate.

The sum of the above items gives the total direct cost. If this be divided by the speed in ft. per hr. the cost per ft. will be obtained. Note that the speed in ft. per hr. is usually given disregarding set-up and fatigue. It is therefore necessary that the set-up and fatigue allowance be added. Actual speed is correspondingly less.

Overhead and investment charges are taken into account, but these must be on the same basis and at the same point in the production line as the item or items to which the final cost is being compared.

Steel, of course, is the usual material to be welded. Occasionally, however, other metals are involved. These are individual problems of special nature. It is interesting to note, however, that steel, brass, copper, and stainless steel are welded by this process. This is indicative of recent advances in the art, such as the control of the arc itself and the conditions under which it operates, the control of the resultant weld metal, and the resultant lower costs.

Specifications for Welded Products

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Chief Engineer, The Austin Company

AS AN art or process develops towards perfection, increased knowledge, skill and technic are required. Naturally, some individuals become specialists and then experts. Eventually organizations are formed. Plant, special equipment and skilled personnel are gathered with the sole aim to produce perfected products. And thus another highly specialized industry is born.

The history of welding is no exception; it followed a course of natural growth. A number of plants, such as the Welding Division of The Austin Company, have come into existence. Such companies have the equipment, expert technical supervision and skilled help that enables them, as a class, to incorporate in their products all the refinements of the art that are available. They, on the whole, are capable of turning out anything within the limits of the development of the art and its associated industries and they keep themselves abreast of the latest developments.

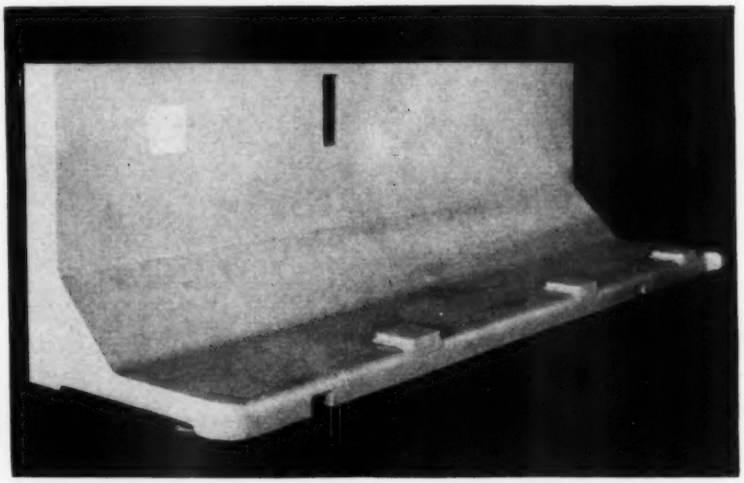
With the birth of this new industry, many designing engineers come face to face with a new problem. If they are to do business with "welderies," they must write specifications for the welding to be done. Material to be used, method of fabrication, welding wire, welding process, stress relieving, cleaning, finishing and testing must all be specified. Even the method by which the plates are to be cut should be specified.

It is well recognized that shearing of plates $\frac{3}{4}$ in. or greater in thickness causes a considerable amount of deformation of the metal and leaves a ragged edge. This indicates that the metal adjacent to the sheared surface has been damaged. Therefore, for all plates $\frac{3}{4}$ in. or thicker, machine flame-cutting should be used, whether the cuts are to be straight or irregular.

Cold Forming

For lighter plates and on pieces where straight edges are required, the plates may be sheared or sawed. But regardless of the method of cutting that might be used, it is highly important that all burrs, fins and ragged edges be removed by filing or grinding before the pieces are assembled. This may seem to be a trivial item but it is highly important that the adjacent pieces fit properly.

Generally speaking, it is very desirable to have formed corners on the machine parts, not only on account of the great improvement in appearance which results therefrom, but also because it is usually more economical to form a corner by bending the plate than it is to make a continuous welded joint between two abutting plates. In some designs, another factor is the question of stress distribution, especially with the lighter plates. Regardless of the reason for cold forming or bending the plate, the minimum radius for cold bending should



This design calls for considerable forming to be done on the plates. The rounded corners give a good appearance and less welding is required

be three times the thickness of the plate. Plates greater than $\frac{3}{4}$ in. thick should not be cold formed. Of course, this restriction applies primarily to the low carbon steels usually used and having a carbon content from 0.15 to 0.25 per cent. If a smaller radius for cold bending is required, a lower carbon content steel should be used. Alloy steels cannot always be bent as specified above.

Welding Wire

Perhaps one of the items most frequently ignored in the design of welded products is the specification of the welding wire to be used. Yet this is of greatest importance. The ordinary bare or uncoated wire, formerly so commonly used, gives a weld that is inferior in elasticity and ductility. If it is used for welds that are later subjected to live stresses, impacts, or shocks, failure may occur. Such welds tend to crack readily.

Generally speaking, it is not now advisable to permit the use of uncoated wire. Although slightly more expensive, all welding wire should be of the coated or covered type. The weld metal deposited by such welding wire should have the following minimum physical characteristics:

Tensile strength...65,000 lb. per sq.in. min.
Elongation.....20 per cent in 2 in.
Specific gravity of deposited weld metal 7.80
Fatigue strength..28,000 lb. per sq.in. min.

The above values of physical properties are those specified by the U. S. Navy. Welded joints, properly made with such wire, almost always fail completely outside of the weld, which gives rise to the common expression, "The joint is as good as the parent metal." Heavy, coated welding wire is recommended for all joints or welds and should always be specified where live stresses, impacts, or shocks are likely to occur.

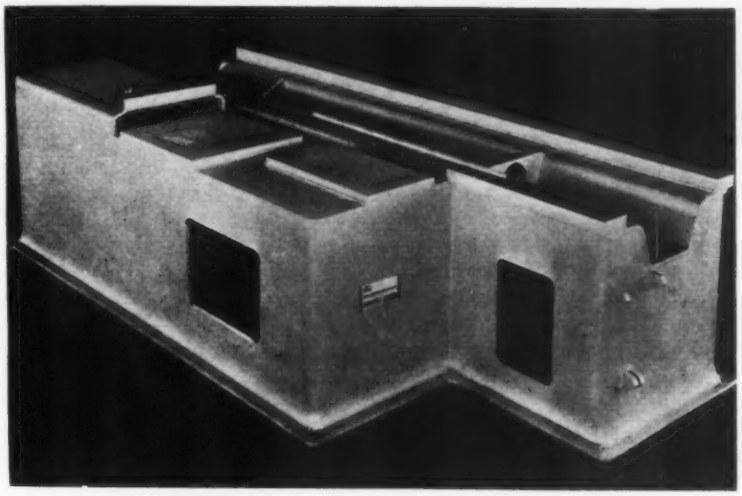
The maximum permissible depth of a single bead fillet weld is $\frac{3}{8}$ in., measured in a manner to be explained later on. It frequently occurs that a deeper weld is required, in which case it should be specified that the succeeding layers shall not exceed $\frac{3}{16}$ in. in average thickness.

When the connection between two machine members must be strong enough to develop the full strength of these members, continuous welds are used. The size of the weld is calculated and specified on the drawing. It must be remembered that it is usual practice to use the minimum size weld when no size is specified on the drawing. In this connection it should be stated that continuous welding, even when not required for strength, is frequently desired on the exterior of machine parts in order to improve appearances.

In addition to savings in cost, intermittent welding has the advantage of removing to a large extent the tendency of the connected members to warp. Whenever intermittent welding is to be used, the amount of weld can be calculated, the basis of calculation being similar to that used in determining the number of rivets and the rivet spacing in structural connections. Two types of intermittent welding are generally recognized. In the 50 per cent intermittent type, a welding bead 3 in. long is laid down and then an equal number of inches of space without welding occurs. In the 33 per cent intermittent type, the bead is 2 in. long with 4 in. space between successive beads.

One of the items that is frequently a subject of discussion is the determination of the size of a fillet weld. It is generally recognized that the size of the fillet shall be interpreted to mean the length of one of the equilateral legs of a right triangle that can be inscribed in the cross-section of the fillet.

In the early days of welding it was usually considered sufficient simply to deposit a welding bead and consider the job finished. Although this might be perfectly satisfactory for simple connections wherein no stress or loads are involved, such an elementary welding procedure would not be suitable for machine frames or elements subjected to stress, vibration or any form of fatigue load. At best, the simple untreated weld cannot be considered in the category of proper welding. Such welds might be compared to white iron castings that have not been heat-treated to make them malleable.



This grinding machine base also shows how corners can be rounded off by using long plates bent or formed to shape. Note the design of the trough

Stress Relieving

Stress relieving begins with the raw material. If the design involves any heavy plates, $\frac{1}{2}$ in. or thicker, and these plates are to be machined over any appreciably large area, they should first be given a stress relieving heat-treatment. This process will assure truer surfaces after machining by relieving the stresses that are often inherent in heavy rolled plates. The process consists of heating the plate to 1200 deg. F., maintaining this temperature for one hour per inch of maximum thickness of the metal, and then permitting the piece to cool gradually and uniformly.

After the plates have been thus properly prepared and assembled for welding and the first welding bead has been applied, the welding beads should be thoroughly peened with a compressed-air hammer using a blunt tool. This operation should be repeated for each layer of welding previous to applying the next layer. The purpose of this mechanical stress relieving is to relieve the cooling strains

that are set up by the heat of welding. It is a method ordinarily used and when properly done gives a satisfactory job of stress relieving. It should be considered, however, as the minimum requirement for all machine parts, and complete furnace stress relieving as the maximum requirement.

A complete job of stress relieving by heat treatment can be given the final assembly similar to the heat treatment previously noted for plates only. Where the equipment is available, the entire assembly may be placed in an annealing furnace. This is a rather expensive process, however, and is usually specified only where the increased cost is warranted. This type of stress relieving does away with most of the necessity for peening, as described in previous paragraphs, and is considered the most thorough job of stress relieving that it is possible to obtain. It should be specified only where the piece is made up of heavy sections or a great amount of heavy welding or machining is involved, and where the part is to be subjected to severe service.

When work is not specified in detail, the question usually arises as to what is to be considered a finished welding job. It should be specified, therefore, that all welds and successive layers of welds shall be brushed clean and free from scale, and slag; all rough spots, sharp corners, or ragged edges shall be ground or chipped smooth, thereby eliminating the necessity for further finishing operations in the shop of the purchaser. In order to facilitate the ease of inspection no filler is to be applied to the welding bead before it has been inspected.

In the finishing of welded machine parts all surfaces, both inside and outside, should be given a shop coat of gray primer before the part leaves the welding shop. Such a specification adds no appreciable cost. The primer coat protects the surfaces during shipment, and eliminates entirely any finishing or cleaning operations in the shop of the purchaser.

Considering the sum total of items that enter into a complete specification for welded parts, one is impressed by the fact that there is a wide range between "ordinary welding" and "engineered welding" of machine parts.

Designing Is a Four-Dimension Problem

ROBERT E. KINKEAD
Consulting Engineer, Cleveland, Ohio

THE manufacture of machinery and equipment parts by use of welded steel assemblies has been going on in this country for some fifteen years. As is the case with most industrial methods, the practice has undergone a process of evolution in fifteen years so that our present conceptions of it are quite different from those at the outset. We see it now as a manifestation of the broad movement towards product engineering.

The design and production of a welded steel assembly for service as a part of machinery or equipment from which certain service is expected is a four-dimension problem. The part will have length, breath and thickness, and, if it is to have value, must have a predetermined service life. A press frame that will withstand 40,000,000 cycles of operation is certainly worth more than one that will fail after 40,000 cycles of operation. The element of time, or service life, is a dimension in the same sense as length, breadth or thickness, and in the world of practical affairs is inseparable from the conventional dimensions with which we ordinarily deal.

We prefer to start the design of a welded steel assembly with a load-space diagram that shows the direction and magnitude of the loads in three dimensions. It is then necessary to block out "reserved space" in which we cannot place material because it would interfere with the functions of the machine or equipment as a whole. Thus we arrive at the direction and magnitude of the loads to be carried and the outlines of the space in which we can put material to carry the loads.

In choice of the form of materials we use, we are subjected to no important restriction other than that the finished part shall have a pleasing appearance from the engineering point of view. This is merely a roundabout way of saying that the structure should be as nearly correct from the mathematical point of view as possible. Designs that are mathematically correct are pleasing to the eye. Nature has known it for a long time. Man is just finding it out. By experience, well-designed formed plates solve more problems than a collection of structural or drawn shapes.

Within the framework of these requirements, we may propose a structure to meet the requirements with which we have dealt up to this time. Having this proposed structure, we may undertake a stress distribution analysis with celluloid, Bakelite or rubber scale models to determine the location and degree of maximum stress in the assembly. Maximum stress is important because failure by fatigue, corrosion, impact or by any of the degenerative influences to which metal is subject, is more likely to occur at the point of maximum stress than at any other point. With such adjustments in the design of the structure as are necessary in view of these matters, the material itself may be chosen. The governing influence is that the material shall be weldable and give the most service life for the money. Most commercial metals are weldable although much remains to be done in the field of high aluminum alloys.

Placing of the welds is governed by the limitations in physical properties of welds and metal adjacent thereto and limitations in the matter of manufacturing facilities for forming plate. In general, welds are not placed so that they are subjected to high frequency reversal of the stress or repeated application of loads of high intensity on account of certain unavoidable discontinuities in welds which reduce their endurance limit. To those who have had experience in the design and production of welded steel assemblies the possibility of making ghastly blunders in welding application is a reality, but in its true perspective welding is a method of joining metals that is incidental to a new phase of product engineering.

Out of this evolution of methods for designing and manufacturing machinery and equipment parts has grown a new industry which is coming over the horizon. The privately operated weldery is well established. The commercial weldery is just starting as an institution. It has already justified its existence and can

pay its way even under present conditions. Modern plate fabricating shops are being sold out at ridiculous sacrifices. Not tomorrow, but perhaps the day after tomorrow, we shall have use for all the modern plate fabricating equipment in the country and create twice that much more.

Better Designs With Less Welding

A. P. WOOD

A.C. Engineering Department, General Electric Company

THE title in itself emphasizes that one must have several years' experience in designing so that he will not fall into the trap of copying the cast design. Though the above is of vital importance, one must also have clearly in mind all the functions of the cast design as well as divorce himself from some of the nice curves so necessary and easy to get when patterns are used. In other words, one must start with a free mind and assemble by welding as few parts as possible of the plates and structural shapes now listed in various handbooks. If these shapes do not fulfill the requirements, perhaps by the use of a brake one bent plate can take the place of two pieces, such as an angle iron welded to a plate.

Do not be discouraged because some other company (perhaps having a different line of product) has a start of several years of designing a welded steel plate product. As a matter of fact, by a careful study of what others have done over several years, it might keep you from the pitfalls they have encountered.

When the average designer starts out to replace a cast product by one of fabricated welded parts, he will get somewhere if the following points are kept in mind:

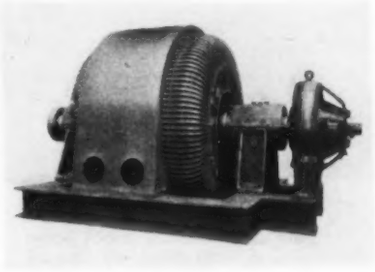
1. Steel plate and structural shapes cost less per pound than cast iron or cast steel.

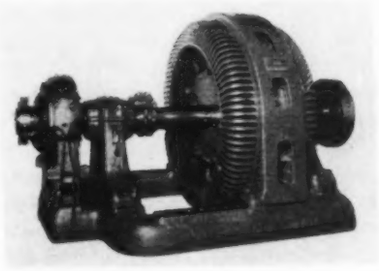
2. Do not dissipate this cost advantage by having your design call for too many parts to be welded together.

3. The scrap material left is a part of the cost. Therefore, it should be a minimum and left in such shape that it can be utilized in other designs for which credit will be allowed on the first design. Large pieces should be bought to template from the plate mill thus saving recutting from the rectangular shapes on which you have previously paid a cutting charge of so much per pound. At the same time, the expensive scrap has disappeared. In other words, it never left the mill so you are not put to the expense of cutting it into smaller pieces for shipping back to the mill.

4. You must use your equipment such as brakes, shear, rolls and torch to advantage on steel plate so that a large percentage of the welding can be done automatically instead of by hand.

5. It costs more to machine steel than cast iron. Therefore, you must design your product to take advantage of welding in such a way as to reduce the number of set-ups, jigs, and machine operations in order to more than compensate for the extra labor and overhead.





Appearance is not a question of the method of construction but is determined by the artistic sense of the man who designs the product

If you have been successful in embodying the above suggestions in your design, you will be surprised to find how little welding you have to do, and how few machine tools have to be used.

In other words, the floor space available for our modern welded product is automatically increased by removing some of the expensive slow moving machine tools which were previously necessary.

The comparison of the picture of the obsolete cast design of an alternating current generator with the picture of a similar generator of modern design using rolled steel plates and structural shapes, brings out the fact that it is possible to make a design that is pleasing to the eye even though the old familiar curves always present in castings have largely disappeared. It can always be accomplished by good engineering.

Evidence that welding was taking hold many years ago is shown in both of these pictures by the curved, sectional, spot-welded oil-protecting shields which began to replace cast iron ones. Unseen evidence could be found in both these machines, such as steel air duct spacers spot welded to the steel core laminations instead of being riveted together.

The art of welding in the design of electrical machinery and apparatus, covering many years, has arrived at its present stage of perfection by a process of elimination. This method can be adopted by other manufacturers in the development of designs to be built by welding.

Vibrations of Structures and Materials

WALTER M. POHL

Assistant Chief Engineer, Kearney & Trecker Corporation

TOO much importance should not be put on the ratio of the ultimate strength or yield point of a material to the computed static stress. Vibrations might alter the conditions, giving rise to fatigue stresses and possibly resulting in failure. But even aside from this, vibrations might be objectionable because of the vibratory motion itself or the noise caused thereby.

Considering only the possibility of

stress failure, a material with a high ultimate strength might possibly fail in a certain class of service whereas a material with a much lower ultimate strength will not fail. The reason for the failure is the introduction of resonance stresses built up by accumulated vibration. This might occur when the material has a low internal resistance or damping factor, thereby permitting the building of vibratory stresses of such a magnitude that failure occurs in spite of the high ultimate strength of the material. On the other hand, a material having a high internal resistance or damping factor will not permit the building up of high stresses through accumulative vibration. Therefore, even if the ultimate strength of the material be relatively lower, failure will not occur.

Internal Damping

From another angle, when resonance is required as in bells or gongs a low damping factor is of prime importance for we know that lead with its high damping factor makes very poor bell material, while on the other hand bell bronze with its low factor provides for a very resonant one.

A complete explanation of what occurs when a structural member is subjected to vibration is given by well-established laws. When resistance is introduced into a vibrating member, for example a tuning fork, the effect of this resistance is to damp out or to cause the amplitude of vibration to decay with time, as shown in Fig. 1. Up to a certain limit the greater the resistance, the shorter the time in which these vibrations are damped out. This limit is known as critical damping, and is the value of the resistance at which the vibration decays in the shortest time. In Fig. 2, the curve *A* represents what occurs in critical damping. If the resistance is increased beyond the critical value, the time in which the vibrating member comes to rest also increases. This condition is designated as "overdamped" and is illustrated by the curve *B* in Fig. 2. However, although it takes a longer or even an infinite time to be restored to its original position, an overdamped structure or material does not tend to vibrate readily. If there were no resistance at all and the frequency of the periodic forces causing the vibration were the same as the natural frequency of vibration, the amplitude of vibration would increase by successive impulses, resulting finally in the destruction of the member.

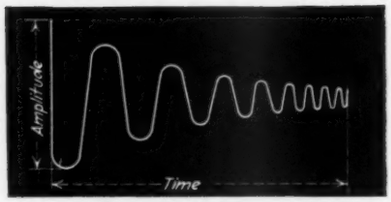


Fig. 1—The effect of internal molecular resistance or the resistance of an applied external force is to cause the vibrations to decay with time

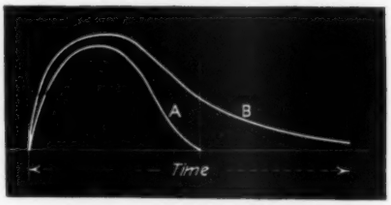


Fig. 2—Curve *A* represents critical damping, the resisting force being such that the vibrations are damped out in the shortest possible time. With a greater resisting force, overdamping, the damping time is increased, as shown by curve *B*

Too often the engineer considers the change in material purely as a problem of computing static stresses and deflections. It is this "stress complex" that the designer must guard against. In machine tools, the absence of vibration and chatter is of paramount importance, and the control of these vibrations is difficult because unlike many other types of machines, they are subjected to an infinite number of frequencies caused by the various cutting combinations. Were it possible to limit cutting to a single frequency, the problem would be simplified because the structure could be designed for a natural frequency below or preferably above that of the imposed impulses. Fig. 3 shows resonance curves for a vibrating structure subjected to various frequencies and clearly depicts the value of the damping factor regardless of the frequency at which the structure is forced to vibrate. It is for this reason that cast iron still holds a prominent place as the material for machine frames, this being based on the inherently high damping factor it possesses. The reason for the high damping factor possessed by cast iron is explained by the structure of the material. Cast iron is primarily composed of free graphite, combined carbon and ferrite. The free graphite not being in solution causes the iron to be somewhat of a heterogeneous mixture. As a result, the vibrations passing through the material have a considerable portion of their energy absorbed by the internal molecular work done in the structure. It is this lack of free carbon or graphite in steel that gives steel a lower damping factor.

As a comparison of damping factors, Fig. 4 illustrates the great dif-

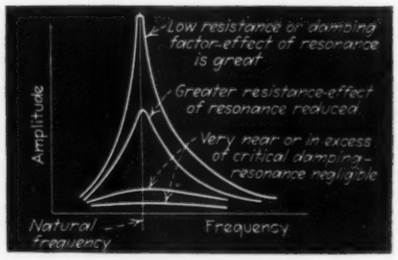

Low resistance or damping factor-effect of resonance is great
Greater resistance-effect of resonance reduced
Very near or in excess of critical damping-resonance negligible
Amplitude
Natural frequency
Frequency

Fig. 3—Here are shown the resonance curves for a vibrating structure subjected to various frequencies. It is evident from the curves that the damping factor is effective regardless of the frequency of the vibrations

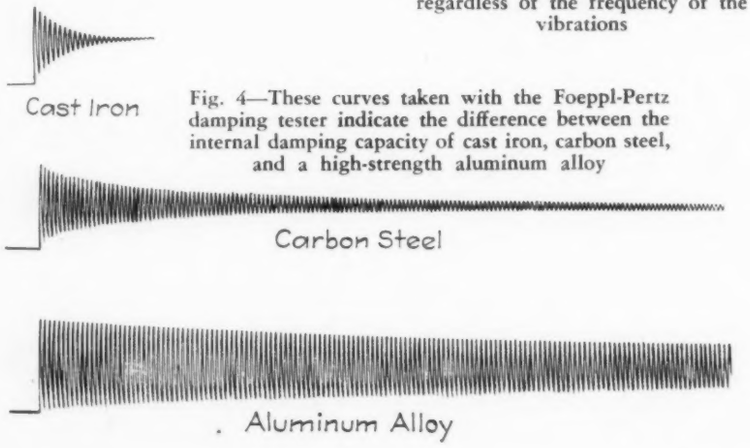


Fig. 4—These curves taken with the Foeppl-Pertz damping tester indicate the difference between the internal damping capacity of cast iron, carbon steel, and a high-strength aluminum alloy

ference between the vibrations damping property of cast iron, carbon steel and a high strength aluminum alloy. These diagrams were obtained from a Foeppl-Pertz damping tester made by the Southwark Foundry & Machine Company. From these curves it can readily be seen that under given conditions a machine member made of cast iron will have its vibrations damped at a very much quicker rate than when the same machine member is made of either steel or aluminum.

Factors in the Problem

A complete mathematical analysis of vibration problems becomes extremely complicated. But a consideration of merely one of the fundamental equations involved will give considerable insight as to the manner in which the basic factors entering into the problem affect the results. Viewing one of the fundamental equations, we have at the natural frequency:

$$X = -\frac{F}{R}\sqrt{\frac{M}{S}}$$

X = amplitude of the forced vibration
F = maximum value of the periodic force
M = mass $= \frac{W}{g}$
W = weight of material
g = gravitational constant = 32.2
R = damping factor
S = elastic resistance or stiffness

From the above equation it can be seen that the amplitude of the vibration will vary directly as the intensity of the periodic force and inversely as the damping factor. It will also vary directly as the square root of the mass, and inversely as the square root of the elastic resistance or stiffness of the structural member. This last factor will vary directly as the modulus of elasticity of the material. It is calculated by dividing the force F by the displacement or deflection it would produce if applied as a static load.

In changing from cast iron to steel or some other material having a lower damping factor the designer must compensate for the change in damping factor by increasing the rigidity or stiffness of the member. In this connection it is to be observed that for a given unit of mass or weight the stiffness must be increased in the same proportion as the square of the damping factor decreases. Failure to take this into account becomes evident most commonly when large flat surfaces are involved, as the resulting vibrations are inclined to be local or largely emitted from the component surfaces which make excellent drum heads, rather than the entire structure which as a whole may be extremely rigid and possess a low mass ratio. By ribbing the surfaces with a lattice structure the rigidity of the side walls per unit of mass or weight, is greatly increased, thereby offsetting to a greater or lesser extent the vibrational effect arising from the lower damping factor. It should be understood that dictates of appearance or practical fabrication may require some particular style of local bracing, depending on the character of the structure, its material, and if welded or cast. It must, however, be borne in mind that the amplitude of forced vibration will increase proportionally to the square root of the mass.

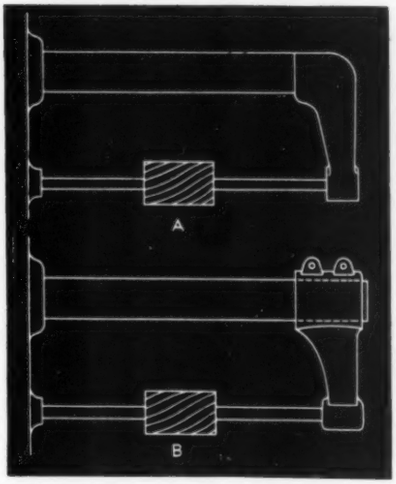


Fig. 5—Damping at joints is an important factor. At *A* the overarm pendant is integral with the arm. In spite of being more rigid than the bolted construction at *B*, it vibrates at a higher amplitude

Effects of Joints

In addition to the damping factor of the material, there is also the damping caused by external forces such as friction, particularly the friction in the joints of connected members. In this manner the vibrations will be damped to a certain degree. Much engineering ingenuity can be used in selecting the type and character of the joint that will contribute most to the isolation of the vibrations.

It is in the design of the connections between the unit parts of the machine where a great opportunity lies for isolating the vibrations or at least preventing their transmission to some particular member where they would be most undesirable. Thus, a fixed-end beam construction is often ideal for the transmission of vibrations, whereas if a simply supported beam construction is used the vibrations can be eliminated almost entirely. This is a matter that can only be decided for each particular field of application and construction.

The leaf spring construction as used in vehicles is a good example of inherently designed "damping factor" which by reason of relative sliding motion between the respective leaves provides frictional resistance.

Comparing the amplitudes of vibration of a leaf spring with one of integral construction having the same deflection characteristics, we would find that the latter would develop an amplitude much higher than the leaf construction. Our present-day shock absorbers are a furtherance of the valuable factor of resistance.

Rigidity versus Vibrations

Another illustration of damping at joints was found in the comparison of the old with the later style of overarm pendants. The old style, as shown at *A* in Fig. 5 is integral with the arm and vibrates at a higher amplitude than the pendant at *B*, which, although bolted, possesses a valuable frictional resistance, greatly offsetting the slight loss in rigidity.

Again emphasizing the danger of the "stress complex," the old style arm under static test proved more rigid by theory and practice, but under operating conditions the periodic forces caused the amplitude of vibration to be greatly in excess of those in the newer style pendant. This is explained by the "damping factor" created by virtue of the resistance of the joint.

It should not be inferred from the above example that bolting is generally preferable to an integral joint where vibration is concerned. But it does show the value of resistance in controlling vibration even though sacrificing a slight measure of static rigidity.

Regardless of the type of construction used, welding or otherwise, vibration is a paramount problem in many types of machines, particularly in machine tools for removing metal. In changing from one material of

construction to another and in changing from one type of construction to another, the vibration factors are changed completely. The previously existing machines had largely been developed from experience and experiment. If this painful path of progress is to be avoided when changing to the different type of construction, it is absolutely essential that a complete analysis be made. Possible failure on account of the different factors involved must be guarded against and advantage taken of the possibilities inherent in the new type of construction adopted.

Constant Strength Structures

EVERETT CHAPMAN

Director of Engineering and Research, Lukenweld, Inc.

NO matter what our design viewpoint, we will have achieved the desired result with the least amount of metal if our structure has a constant strength throughout, that is, if the stresses at any point in the structure are of the same order of magnitude as the stresses at any other point. I say "order of magnitude" since this condition is by no means easy to obtain. Only when the line of action of the loading is coincident with an axis of symmetry of the structure can we be sure that we have constant strength. An ordinary tension test specimen pulled in a tension machine is one illustration of a constant strength structure; a hollow spherical vessel subjected to internal pressure is another. It would seem that only when we can imaginatively substitute ropes for the structure actually used can we achieve a constant strength structure.

Stresses in Fillet Welds

The distinguishing feature that indicates a complex structure is the presence of bending moments. Any structure which by its specified nature requires metal placed at right angles to the direction of the load or a component thereof, has bending moments present. From then on the engineer can well afford to indulge in a minute scrutiny of the contours.

"Mathematically correct" is a fine sounding phrase but it is far more practical to be able to say that a certain structure is experimentally correct. The engineer will find freedom in the laboratory, and the degree of his emancipation will depend only upon his excellence as an observer. The experimental methods that can be focused in an attack upon difficult types of structures are numerous.

The results of an attempt to delineate the stress distribution and elastic behavior in a pair of fillet welds used to join a thin member to a thick member are presented here. The simplest test to which we can subject a joint such as this is to pull it in a tensile machine. The disturbing feature of a joint of this type is not only the fact that the weld contours themselves may be somewhat

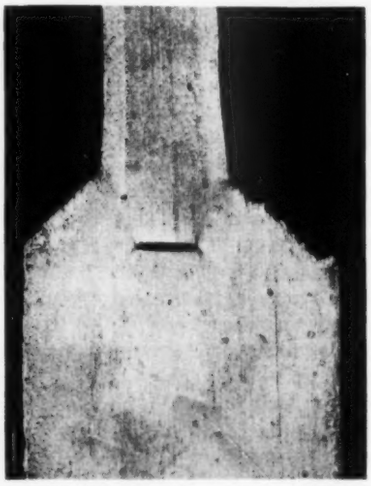


Fig. 1—Fillet welded joint after destruction test. The unwelded crack, which was barely discernible before pulling, has opened. The radius around the ends has become larger and the metal has become strain hardened. Both effects strengthened this joint to such an extent that failure took place 4 in. from the weld

irregular, but that we have left upon the interior of the joint an unwelded boundary, an internal defect. Under an axial tensile load, we note at once that the metal at the boundary of this internal defect is at right angles to the load. We may therefore expect to find at the end of the defect some rather grave bending moments acting on a small volume of metal.

Fig. 1 shows the result of such a tensile test. The deposited metal was of a ductile nature, having an elongation of 30 per cent in 2 in. We may expect that the ductility of the metal will contribute to the structure's attempt to relieve itself of the stress concentrations that are present. It is to be noted that the metal around the crack or unwelded boundary which was formed by the two fillet welds

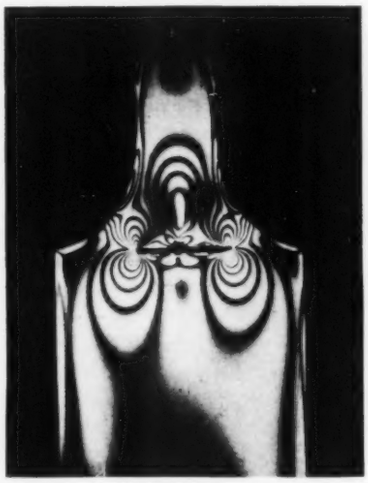


Fig. 2—Stress distribution around a fillet welded joint. The principal stresses are deduced from the loci of the maximum shears

tended to relieve its precarious position by increasing its radius at the end of the crack. It was able to do this because of the plastic action of the material in the welds. As the radius at the end of the crack grew larger the stress distribution tended toward uniformity. This is the main function of ductility in a statically loaded structure. After this specimen had relieved its worst spot to a considerable extent, failure occurred 4 in. from the weld. We thus have the combined properties of ductility and strain hardening operating to produce a constant strength structure.

Our next powerful experimental attack is the use of polarized light and Bakelite specimens to find out why the joint behaved as it did. Fig. 2 shows the stress distribution throughout the type of joint we are discussing. The black lines are lines of constant maximum shear and by properly interpreting the order of these lines at the boundary, we are

immediately able to evaluate the stresses at the boundaries. The greatest stress is to be found where the black lines bunch up on the boundary. The photoelastic method checks the tensile test in that it indicates that the maximum stress occurs at the ends of the unwelded boundary and that that is the point where yielding first took place in our tensile test.

If the material in the weld had not possessed ductility, the initial stress distribution would have been maintained up to the point of ultimate

Fig. 3—Lead model of a fillet welded joint loaded to destruction. Lead has a high ductility and very little elastic strength

failure, in which case the failure would have been through the weld metal, starting at the point of maximum stress. This would have been the result had we employed a poorly executed bare wire weld to make the two fillet welds.

Let us now pull a lead model of this same type of joint. Lead has practically no elastic limit. Its behavior is entirely plastic throughout most of its range. A broken test specimen of this material is shown in Fig. 3. Note that the extreme ductility operates to smooth out the structure and to bring its maximum stress more nearly in line with its average stress. Lead illustrates the remarkable ability of a ductile material to place the boundaries of the load carrying metal parallel to the line of the applied force. Ductile materials enable us to build up to a certain limit, a "self-healing" structure to take care of our design mistakes. But this holds only for those imposed loads that are static in nature.

Fig. 4—Failure in a plaster of paris model starting at the point of maximum stress. There is no ductility to alleviate stress concentration

When we are considering dynamic loads, which cause fatigue failure, we can no longer count on ductility to smooth out our design mistakes. A fatigue failure occurs at stresses below the elastic limit, and is not accompanied by any permanent deformation. To get a picture of the nature of a fatigue failure in a joint we may employ in a model a material whose ultimate strength corresponds to its yield strength. We will then have a failure whose starting point is the point of maximum stress which stress has not been alleviated by a change of shape. Such a material is plaster of paris. Fig. 4 shows the failure of a model made of this material. The failure again checks the behavior and phenomena exhibited by the three preceding materials.

Model Analysis

We have through the use of simple and quickly executed experimental methods made a complete survey of the behavior of this rather complicated joint. We know the stress distribution throughout the joint. We have located the point of maximum stress. We can get an idea of its magnitude from a study of the maximum shear lines in the photoelastic test. We know what degree of ductility is necessary to make this joint safe in a statically loaded structure. We know what its fatigue fracture will look like, where it will start and the cause of it. The lead model has given us a design philosophy concerning the proper placing of material.

It is a small matter to go from the illustrations provided to model analysis in two or three dimensions in any sort of structure. Only one word of caution must be extended to those who wish to use models. In making a model of a structure, the replica must be true. It must faithfully duplicate to a scale all the details, the entire configuration and all the relative dimensions of the large structure that in any way have to do with the behavior under investigation. A caution to be observed here is that the smaller the scale of the model the more accurate must be the measurements, since many of the related quantities vary as the square or cube of the scale of reduction.

Machine Tools Built of Rolled Steel

An Interview With

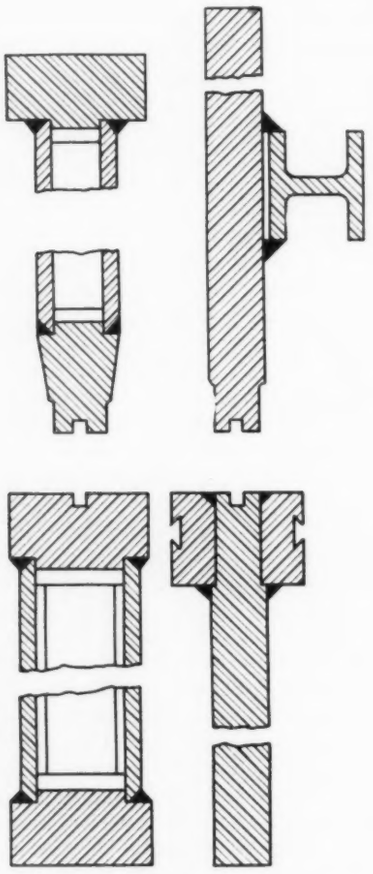
R. T. HAZELTON

V. P. in Charge of Engineering, Cincinnati Shaper Company

IT SEEMS to be unfortunate that so much emphasis has been placed on the word "welding." Why stress a manufacturing process, when the important fact is the materials and design possibilities that this method of construction has made available to all designing engineers? Apparently the failure to recognize this fact is one of the reasons why so many designing engineers fail to rid their minds of the restrictions imposed by cast construction and to take advantage of things that can be done with rolled steel. The tendency seems to be to stick to the same general type of construction as was used for the same or similar products made of castings.

The necessity for providing fillet and draft, and for avoiding abrupt changes in cross-sections, excessively thin webs and similar factors, are requirements and restrictions that are confined to castings. Practically all engineers recognize these restrictions,

but it is equally important, and perhaps more so, that they take advantage of the new material they are using and the forms in which it is available. And above all, they must get away from the "traditional" forms of cast construction which can only be done by a complete study of the problem.

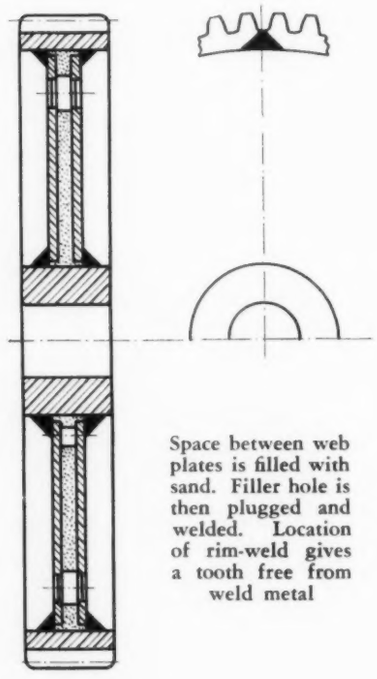


Built-up welded box sections are shown to the left. To the right—solid rolled-steel plates are used for the ram and bedplate

Types of Construction

An analysis of the forms or types of construction that characterize castings brings out some interesting points. Take, for example, castings that are to serve in the nature of beams. They are generally made as I-sections or as channel sections. They are essentially plates or webs with heavy ribs along the upper and lower edges. This distribution of material gives the biggest section modulus for the least amount of metal. On account of the method of making the castings, the saving of metal is accomplished without adding any other appreciable expense.

If it were more expensive to make castings with heavy ribbing and the nature of the part did not demand minimum weight, rectangular cross-sections would be used in place of the I-section or a channel section. But in machine frames and parts extra weight is often an advantage, a fact that is now becoming more generally recognized. Particularly in products such as machine tools, heavy masses contribute to absorbing vibrations. Such a feature must then be evaluated in terms of dollars and cents. If the added weight costs relatively little, it is usually sound engineering practice to add it. In addition, if the cost of economizing on the material is greater than the value of the material saved, there is no longer any doubt as to the thing to do.



Space between web plates is filled with sand. Filler hole is then plugged and welded. Location of rim-weld gives a tooth free from weld metal

In the development of our design of press brakes made of rolled steel one of the first questions that we had to decide upon was the type of beam section to be used for the bedplate and ram. There were three general types from which to choose. Naturally the first thought was to imitate the castings, that is, weld a top and bottom cord to a flat plate. The required lateral rigidity was an important factor and would limit the minimum thickness of the web. But for a given total thickness of web plate the lateral rigidity can be increased by increasing the moment of intertia about the longitudinal axis of the beam. One way to do this is by using a box section, which is easy and economical to make in welded construction but which is expensive and not always practical to get when cast construction is being used.

Solid Plates

In the accompanying figure is shown the box-type design of the bed and the ram as at first developed. It should be mentioned that at the time this design was made heavy rolled plates such as we have today were not readily available. It was recognized at the time that, for reasons that will be explained, the solid rectangular cross-section shown at the right of the illustration would be far superior to the hollow rectangle. Therefore, as soon as sufficiently thick plates became readily procurable, the design at the right of the figure was adopted.

Comparing the box-type and solid-rectangle cross-section, it will be noticed that the box-type ram requires 32 linear feet of welding for a ram 8 ft. in width. Use of a solid plate eliminated this cost item, which saving is more than the cost of the additional steel in the solid-plate type of ram. Also, one weakness of the box-type ram was the danger of one or the other of the relatively thin side plates buckling or warping slightly, which would compel the die holder to twist or get out of alignment. Similarly, in this design it was impossible to put an adjustment member on the back face of the gate. As shown in the figure to the right, in the design of the solid-plate ram a heavy H-beam was welded at its ends to the back face of the ram. Tension and compression screws located at different points along the length of the beam make it a simple matter to adjust the ram for alignment throughout its whole length to an accuracy within 0.002 in. In the box-type design, such a provision for adjustment would not be possible.

In the lower views of the same illustration are shown the box-type and solid bedplate designs. The total amount of welding is the same for both designs. The reasons for the superiority of the solid plate are similar to those given above for the solid-plate type ram. And another factor, common throughout, is the advantage gained because of the greater

weight of the members, for reasons as explained above.

A detail of design that aptly illustrates the need for a perfect balance between cost and quality is shown in the solid-plate bed in the lower right-hand figure of the illustration. The cheapest thing would have been to have welded the slotted side members along the top edges of the bedplate directly to the face of the plate. But this would have put all of the load on the welds. By machining a shoulder into the plate and making these side members butt against the shoulder, the welds are relieved of much of the load. The cost of planing the bedplate is insignificant when considered in the light of the improvement obtained thereby.

In another one of the accompanying illustrations is shown the finished press brake as finally developed. A detailed account of all of the refinements in the design and how and why they were brought about would require much space. But as the same engineering considerations will find possible application in many other product designs, a brief resumé will be given here.

Simple-Beam Construction

To prevent any deflections from being transmitted from the bed to the end frames, the bed is supported by the frames as a simple beam. A shoe having a curved radius fits the curved abutment of the bedplate. Another radius at right angles fits the curved portion of the bed, as shown in the picture on another page.

Frequently a little thought and attention given to the "minor" points of the design results in improvements in other respects. In the operation of press brakes it is frequently necessary for the operator in front of the machine to talk to his helper on the other side of the ram. In view of this it was decided to provide circular "windows" through which the operator and his helper could carry on a conversation. Not only do the windows fulfill that purpose but they also improve the appearance of the machine.

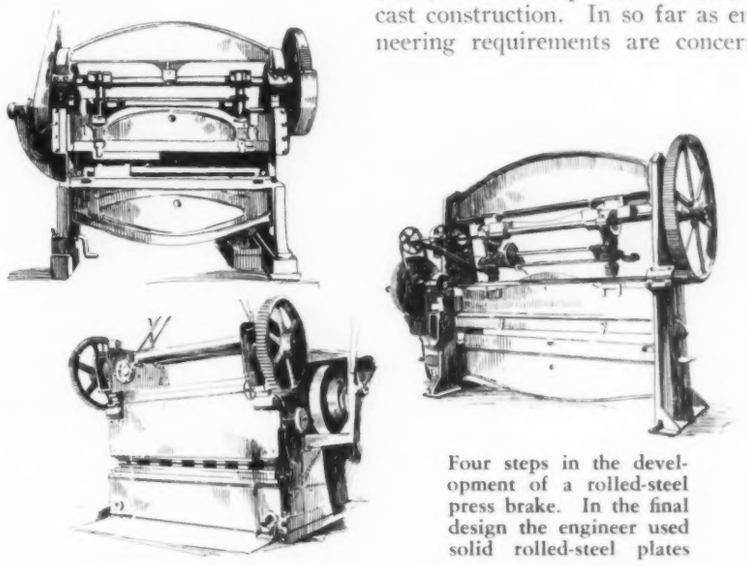
In our first design of welded main gears, a single plate web was used. Vibrations made the gear ring loudly. When hit with a hammer, the sound was like that of a high pitch bell. Numerous methods of sound deadening were tried, and finally the design shown in the accompanying illustration was developed. The space between the two web plates is filled with dried sand, the effect of which is that a dull tone is the only sound that can be given off by the gear. The filler hole is plugged and welded, the sand being thereby positively retained between the gear wheel web plates.

Another detail in the design of this gear is the location of the junction weld in the rim. The gear is cut so that the weld comes between two teeth, that is, at a tooth space. This detail of design was original with the Cincinnati Shaper Company and has become commonly accepted as the proper method in the design of welded gears.

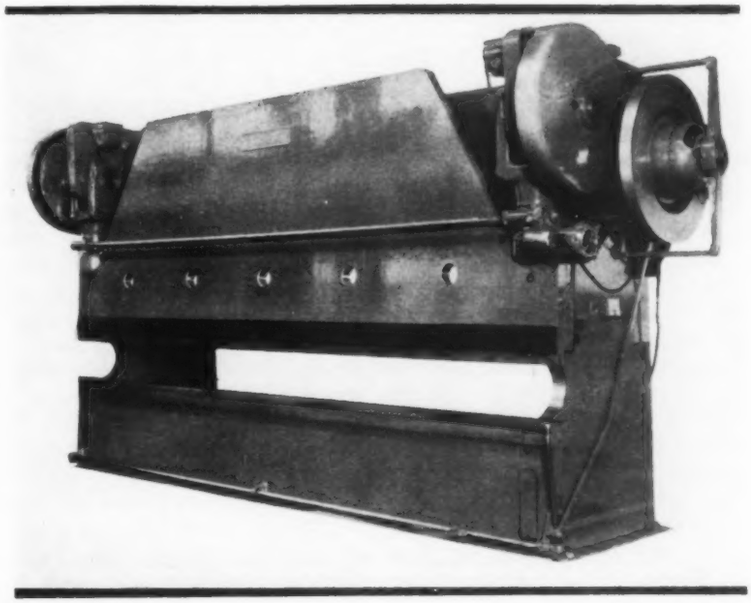
Frequently it is the small and apparently insignificant detail that makes the most striking differences. At the same time, it is when dealing with the little details that the engineer is most likely to make the mistake of imitating cast construction. This is because he fails to fully analyze the little problems. The question of bosses for bolt heads illustrates the point.

Pads and Bosses

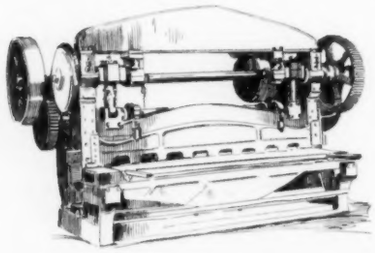
A little study will quickly show why the design of a bolted connection should be entirely different for rolled steel than in the case of cast iron. It costs practically nothing to put a boss on the surface of a casting and to spot face the boss to give a smooth seat for the bolt head. But to make a similar boss on the surface of a rolled plate it would be necessary to cut and face a disk and then weld it to the plate. This is relatively expensive and is no improvement over the cast construction. In so far as engineering requirements are concerned



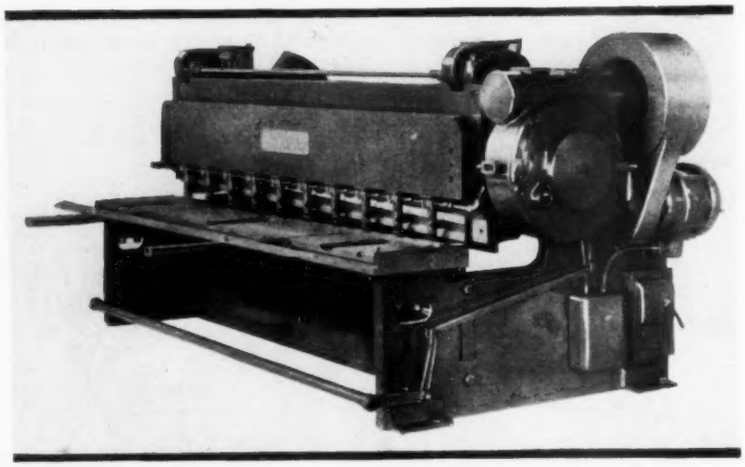
Four steps in the development of a rolled-steel press brake. In the final design the engineer used solid rolled-steel plates



a boss is not necessary for this purpose if the plate is of sufficient thickness to permit counterboring the bolt hole. With a counterbored hole, and using a hollow-head screw, it is a superior construction. Projecting bolt heads usually detract from appearance and in many instances



In redesigning for rolled-steel construction the engineer has the opportunity of creating something new. This squaring shear, as compared to the one to the left, is an example



are also a source of danger. In the accompanying illustrations of the rolled-steel press brake and the rolled-steel squaring shear, it can be seen how the flush surfaces, made possible by using recessed hollow-head bolts, greatly add to the appearance of the product.

Raised Pads and Bosses

Sometimes it is absolutely necessary to have a boss. Under such conditions it is far better to build up the boss completely with arc welding rather than welding on a separate pad or disk. At the best, a pad can be welded only around the edges. Hence, except at the edges, there is likely to be space between the disk and the plate to which it is welded. On the other hand, building up the boss entirely of weld metal gives a solid construction throughout.

Raised pads, so similar to bosses, present a somewhat similar problem. In many designs, a relatively thin plate is welded to the surface of the plate that is to have the pad. Only the edges can be welded, with the result that almost invariably a space is left between some portions of the welded-on pad and the baseplate. When the part which is to be supported by the pad is placed upon it, it does not receive firm support. Also, this method of obtaining raised pads is relatively expensive on account of the great amount of welding involved. A more economical design, superior in every respect, is to plane off the plate so as to leave raised pads. With high-speed planing, this is a relatively inexpensive operation.

The above two examples relating to the design details concerning bosses and pads strikingly illustrate how easy it is for the engineer to lose sight of the results to be accomplished. There is always the tendency to revert back to casting practice. But if each detail of the design is closely questioned and analyzed, it will be found in most instances that the best method for getting the desired results in rolled-steel construction is entirely different from that for cast construction.

When developing the design of the product that is to be made of rolled steel instead of cast iron, the engineer is using a material that has a modulus of elasticity about two and one-half times that of cast iron and a tensile strength approximately twice as much. Also, the cost of the material on a pound basis is about one-third that of cast iron. As most mechanical structures, particularly machine tools, must be designed for limited deflections, the higher modulus of elasticity of rolled steel presents a great advantage. Of course, the greater strength of rolled steel over cast iron is an advantage in many instances.

With reference to the relative cost of rolled steel and cast iron, it is regrettable that in the past, and even to a large extent in the present, a disproportionate amount of emphasis is put on the cost item. It seems that as soon as it is decided to use welding, everything is done to cut out every item of expense without regard to cost-value ratios. No engineer would for a moment consider using castings without having the gates ground off, sandblasted, or perhaps tumbled. Surface holes in castings are always filled and smoothed over. Sharp corners are ground. Yet every day we see crude-looking welded products wherein the welds appear just as they were made originally and jagged edges are left unground.

Appearances

This same general statement also holds true for the amount of attention that is given to machine-finished surfaces and machined fits in the design of rolled-steel products. Too many engineers seem to feel that if welding is used machining is to be avoided as much as possible. No argument is needed to condemn such engineering practice. It is undoubtedly the result of a misconception of the function of welding, which should always be considered as a means for joining pieces and not as a method for cheaply imitating a cast product. Regardless of the method of construction used, the same standards of quality should be applied if the products are to be comparable.

Like all other things, welding has both its field and its limitations. One mistake is to become over-enthusiastic and design every part as a welding. In many instances a close study of the problem will show that it is uneconomical or unprofitable to design smaller parts to be of welded construction. Usually small bell cranks, levers, and many irregularly shaped parts are more practical, less expensive and better looking if made as castings.

As can be seen from the accompanying illustration, and from the

A shoe with cylindrical bearing surfaces is used as a filler between the bed and bedplate, supporting the latter in the manner of a simple beam

brief description that is given here, the Cincinnati Shaper Company pays a great amount of attention to quality, appearance and finish. All exposed welds are ground and filled. All sharp corners are rounded off by grinding. Wherever a machining operation can be used to advantage, it is so specified. They always look upon welding as an economical method for joining parts and not as a means for making "cheap" products.

With the tremendous impetus that has been given to welded construction, many companies are now in the process of redesigning their products. Herein lies a great opportunity for designers. Instead of merely substituting welded parts for castings, the engineer should take advantage of the situation and make every effort to create an entirely new and superior product that shows visible improvement over the one it replaces. Much can be accomplished when the designing engineer tackles his problem with the sole object of taking every possible advantage of all the materials, construction methods, and unit parts that might be available.

Design Details

In the all-steel shear illustrated here, a worm-gear drive supplants the customary pinion and gear. Hydraulic holddown pistons, each pressing down on the plate with exactly the same equalized pressure, are used in place of the holddown bar. The path of the shear blade makes an angle of two or three degrees with the vertical so that when the blade makes contact with the top surface of the plate being cut, the cutting edge of the moving blade is directly above the cutting edge of the lower stationary blade. This arrangement is equivalent to cutting with zero clearance, puts the plate in perfect shear and results in a clean cut. The significance of this can be gained from the fact that with this shear it is possible to cut a strip off the edge of the plate, the width of the strip being only one-third the thickness of the plate.

Although none of these last-mentioned improvements was made possible by the virtue of welded construction, it is significant that in the design of this machine every phase of the engineering problems involved was investigated thoroughly, every advantage was taken of the advances and developments in industry, and the whole engineering problem was tackled as one that demanded originality of thought and conception. When all is said and done, if in the development of a new product only one phase of the engineering problems is given consideration, the results, of necessity, must be like a new patch on an old suit.

▼ ▼ ▼

Editor's Note—In the articles that comprise this symposium one is struck by the emphasis that is repeatedly placed upon the necessity of applying engineering fundamentals. On the other hand, it is also made apparent that the same engineering principles that must be applied in the design of parts and structures to be made of rolled steel and welded, apply equally well to all types of construction. From this angle it might seem out of place to discuss such factors as vibrations, fatigue and stress concentration relative to welded construction only. But the fact is that on account of the all too usual habit of imitating or thinking in the terms of cast construction, some of the design factors are likely to be overlooked or ignored.

Some engineers may disagree with certain statements contained in the preceding articles. Others may feel that insufficient stress has been placed on certain factors or that certain other ones have been omitted entirely. Some may disagree entirely with certain of the opinions or statements of facts as given. The editors of *Product Engineering* will feel indebted to those who may submit discussions of this symposium for the reasons mentioned.

"Herein lies a great opportunity for designers . . . Much can be accomplished by taking every possible advantage of all the materials, construction methods and unit parts that might be available . . ."

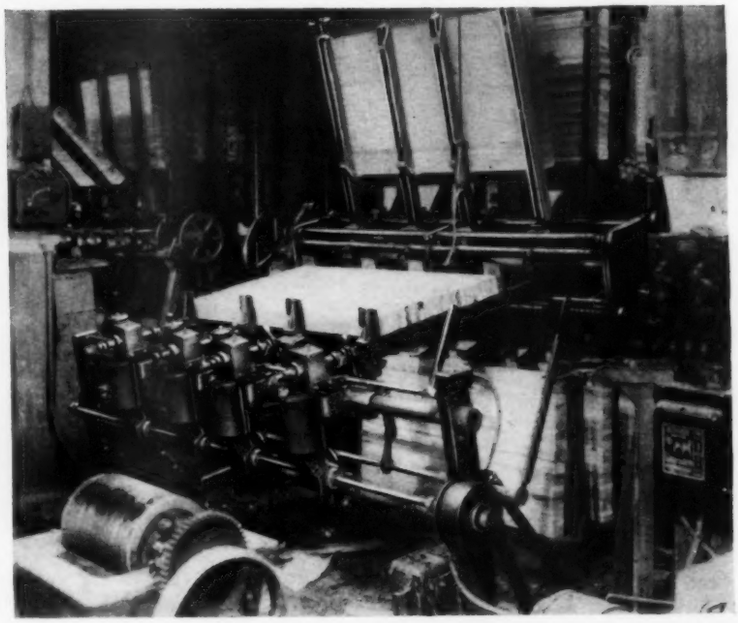
PRODUCT DEVELOPMENTS

New Material Uses—Interesting Application of Friction Clutches—Automatic Lighting Control for Buckingham Fountain—Rotary Pump with Rotors of Novel Form—Cadmium Plating in Unusual Applications—New Railroad Wheels — Vibration Absorption — Blind Screw Fastenings

▸ New Material Uses

Aluminum alloy castings are being used extensively in the construction of a new yoke-type compression riveter recently developed by the Hanna Engineering Works. Other major parts are either hardened and ground alloy steel forgings or heat-treated alloy steel castings. The result is an unusually light and compact riveter for portable use, weighing but 170 lb. but developing 15 tons between the dies. This pressure is sufficient for cold-heading $\frac{5}{16}$-in. diameter rivets.

Another use for aluminum is found in the heat-resisting coating used on the motor block, manifold and exhaust pipe of the 1933 Dodge cars. This coating, called "Permite Resalum," is said to have withstood tests wherein the manifolds reached a temperature of 1,400 deg. F. This new aluminum coating is ready-mixed in a synthetic resin vehicle.



Clamp adjuster of the Cincinnati Clamp Company wherein all of the clamps are driven through adjustable friction clutches

In a new screw cutting lathe recently put on the market by the Atlas Press Company, the designers use 43 zinc die-castings including such parts as gears, gear housings, gear carriers, pulleys, handwheels and graduated dials. The New Jersey Zinc Company reports that these die-castings show a tensile strength of from 40,000 to 45,000 lb. per sq.in.

Word comes from Russia that the blades in each of the four 37,500-hp. Kaplan runners for the Swir III hydro-electric plant are built of stainless steel. These runners are 24.35 ft. in diameter. As a contrast in size, stainless steel is now available in control cables for aircraft. This application in the aeronautic field follows the successful usage of stainless steel rigging for sailing craft. In addition to being highly resistant to corrosion, this type of alloy steel cable is said to be practically non-magnetic, an important consideration where control wires run through cockpits in the neighborhood of magnetic compasses.

▸ Interesting Application of Friction Clutches

Although friction clutches adjustable for transmitting a limited required torque have been in use for some time, an interesting and new application of them is found in the clamp adjuster of the Cincinnati Clamp Company. In their design of a special type of apparatus for clamping material of considerable length during gluing operations, the clamping screws are actuated through adjustable friction clutches.

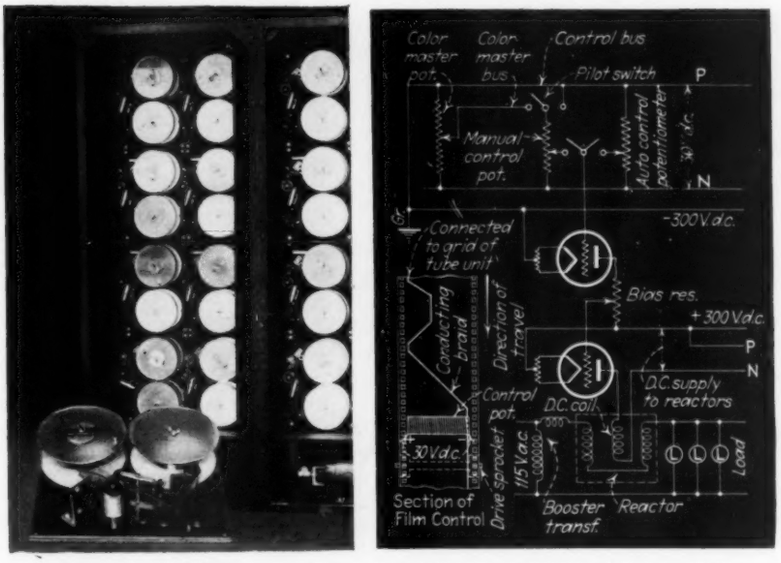
Each clamping screw is fitted with a T-head and each one of the driving heads contains a clutch. As can be seen in the accompanying illustration, all of the clamping screws are turned up simultaneously. By a simple adjustment of the clutches, equal pressure is applied by each of the screws. Such a clamp-driving mechanism can be applied to any standard clamp carrier such as used in the woodworking trade for clamping material.

▸ Automatic Lighting Control for Buckingham Fountain

Visitors to the Century-of-Progress exposition in Chicago this year will have an opportunity to see the Buckingham Fountain with its automatic lighting control designed by the engineers of Westinghouse Electric & Mfg. Company. In this design the

pattern for any given lighting effect is laid out on an insulating film with a conducting braid, the curve of the braid depending upon the intensity of the light desired. This film is passed over a control potentiometer, the braid on the film being connected to a vacuum tube circuit so that the varying potential on the braid as it passes over the potentiometer varies the output of the tube units. This acts through a saturated core reactor to change the intensity of the lighting circuit with which it is associated.

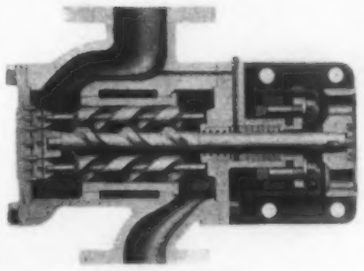
By having one of these controls for each lighting circuit involved and by laying out in advance the desired curve of conducting braid on the film, it is readily seen that any program may be predetermined and exactly duplicated, thus doing away with any possibility for human error in the process.



From left to right: one of the automatic lighting control units for the Buckingham fountain; a portion of the control board incorporating these units; a section of the film control; a schematic diagram of the lighting control circuit

▸ Rotary Pump with Rotors of Novel Form

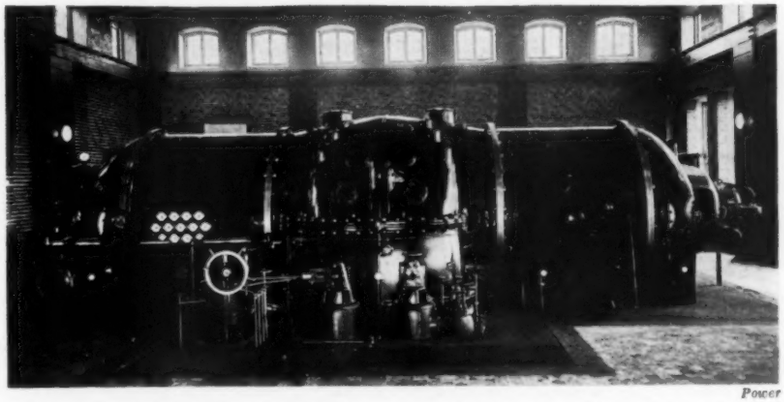
High speed has generally been considered impracticable for rotary displacement pumps. But in a new pump recently designed by the engineers of DeLaval Steam Turbine Co., power is applied to a central power rotor, which meshes with one or more sealing rotors of such form that they are propelled largely by fluid pressure with a minimum mechanical contact.



Axial section of the DeLaval-Imo rotary displacement pumps wherein power is applied to a central rotor which meshes with two sealing rotors that are propelled largely by fluid pressure

This action results from the shape of the threads, those of the power rotor being convex, while those of the idler rotors are concave. This tooth form, which is patented, accomplishes sealing so effectively that numerous turns of the thread around the rotor, as found in conventional screw pumps, are not required in order to keep slippage to a small value. It is claimed that efficiencies of 80 to 90 per cent have been obtained on independent impartial tests.

The velocity of the liquid through the pump is low and there is no trapping or cutting off of liquid in tooth pockets, as in some rotary displacement pumps. Because of this, and the fact that there is nothing in the mechanical construction to limit the operating speed, the pump operates successfully and quietly at the higher motor speeds, and even at turbine speeds. There are only three moving parts, and except for small thrust buttons to maintain the relative axial positions of the rotors, no separate bearings are used, nor are pilot gears required. Only one stuffing box is necessary.

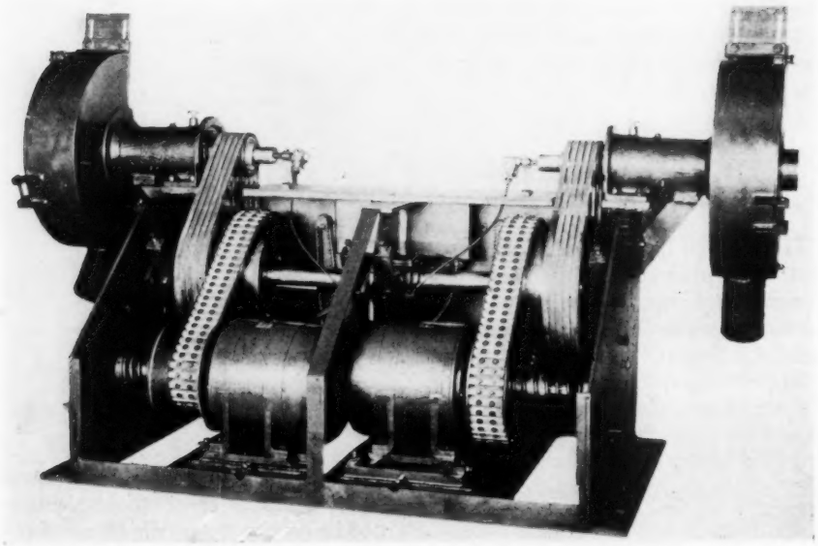


Power

Ljungstrom 50,000-kw. turbine at Vasteras, Sweden, is the world's largest of the double-rotating type. Steam expands radially instead of axially and a world record efficiency ratio of 90.3 per cent is reported. Total weight 510 tons, rotating parts 52 tons, length equal to that of a 15,000-kw., 3,000-r.p.m. axial turbine

▸ Cadmium Plating in Unusual Applications

From France comes word that a Parisian cosmetic firm had difficulty with finishes on lip stick cases, which were badly corroded by the contents, and that cadmium plating proved to be a satisfactory solution. Cadmium plating is also used in France for protecting the negative plate in lead accumulators. The purpose of the coating is to prevent oxidation of the plate while in storage. Gelatin hardened with formaldehyde, silica gel and slaked lime coatings were



The engineers of the Production Equipment Co. have designed this variable-speed floor grinder which incorporates Reeves variable-speed pulleys, tachometers for easy speed adjustment, and ball-bearing countershafts which can be adjusted to take up stretch in the V-belts of the countershaft drive

used before but without complete success.

In this country Udylite Process Company reports that certain ball bearings are being cadmium plated for rust-resistance and to facilitate wearing in. The plate flows into crevices and some remains on the flat surfaces for protection. Other examples include plating of worm gears and ball joints. Even fine instrument parts are being cadmium plated for the combined purpose of preventing rust and friction.

Cut-away section of the new hard rubber pipe coupling developed by the American Hard Rubber Company, showing the soft rubber teeth (see arrows) which engage the hard rubber pipe when pushed into place

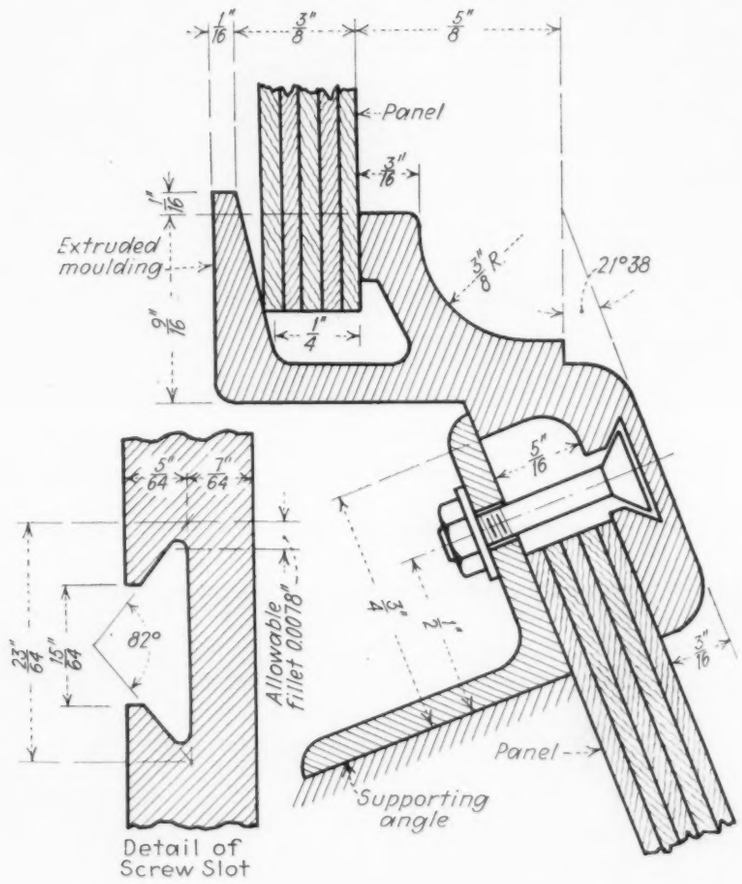
▸ Blind Screw Fastenings

The accompanying detail drawing shows the principle of design used by the Otis Elevator Company in mounting the moldings for their balustrades on escalators. The main purpose of this design is to hide the screw fastenings.

All of the moldings are extruded out of architectural bronze, 13 per cent nickel-silver or aluminum. For the aluminum moldings, alloy 43-S or 51-SW of the Aluminum Company of America are used.

Other advantages of this type of design are that it eliminates drilling operation and greatly simplifies the assembly. The countersunk head screws are simply slid along the screw slot to positions where they are opposite the holes in the supporting angle. The groove to receive the plywood paneling is tapered so that the panel can be wedged into place.

When the assembly of panels and moldings has been completed, the various elements lock each other into position, the only fastening used being the countersunk head screws.



To prevent them from turning in the slot, "countersunk" square-head screws are used, only two opposite sides of the head being beveled. Tapered grooves simplify assembly and assure a tight fit for the plywood panels. Different shapes of extruded sections using this principle can be designed for specific applications

▸ New Railroad Wheels

In the new type of wheel announced jointly by the Clark Equipment Company of Battle Creek, Mich., and the B. F. Goodrich Company of Akron, Ohio, rubber is used primarily for the absorption of noises and to procure greater resiliency.

Four disks 23½ in. inside diameter

and 27 in. outside diameter, of specially compounded rubber, $\frac{1}{4}$ in. thick and $1\frac{3}{4}$ in. wide, are placed in each wheel under lateral compression. The load is carried entirely by shear, the shear deflection being the same at all points, thereby distributing the load practically uniformly throughout the rubber. Shear load is only 7 lb. per sq.in. In the usual design of cushion wheels, with the rubber under compression load, only the lower half of the rubber carries the load.

Contrary to previous practices, the rubber disks are not vulcanized to the metal, slippage being prevented by the lateral compression of the rubber disks between knurled plates.

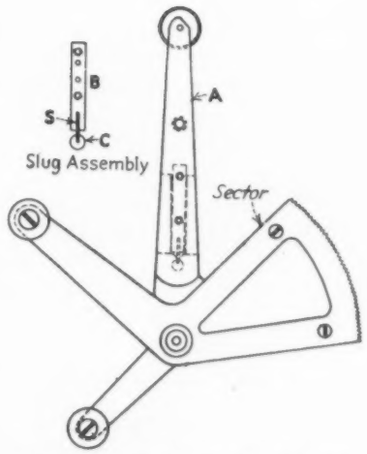
Recently the double-disk main driving wheel centers, developed by the Scullin Steel Company, successfully completed a 13-months' test in service. The design of these locomotive wheel centers is shown in the accompanying figure. It is claimed that compared to the conventional spoked wheel center, these wheel centers have about 50 per cent greater lateral strength, show an appreciable saving in weight and, on account of the greater uniformity of the section, eliminate many foundry difficulties. Better quality and more uniform castings are therefore obtainable and there is little danger of warpage.

For the locomotive designer, one important feature of this new design is the greater volume available for adding weight for cross and counterbalancing. This is particularly valuable in the case of small wheels which, of the spoked design, sometimes do not permit the addition of sufficient weight to get complete balancing.

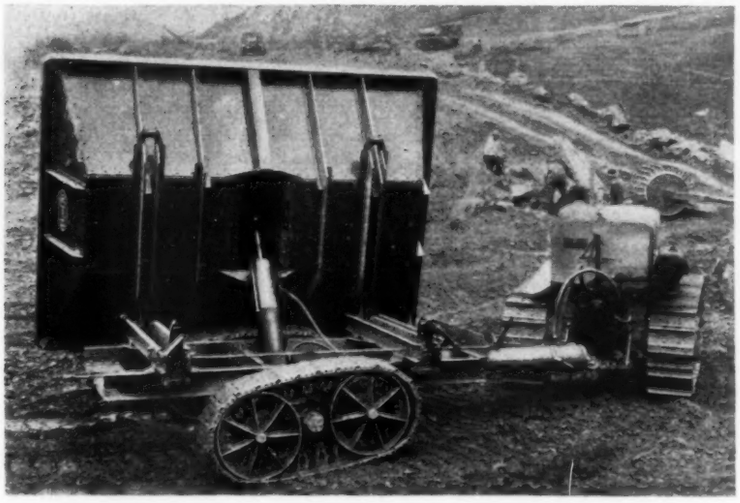
▸ Vibration Absorption

In the redesigned Kron scale, a small leaf spring is used to connect the sector arm to the sector that drives the pinion on the pointer shaft. The purpose of this design is to absorb the vibrations so that they will not be transmitted to the pointer.

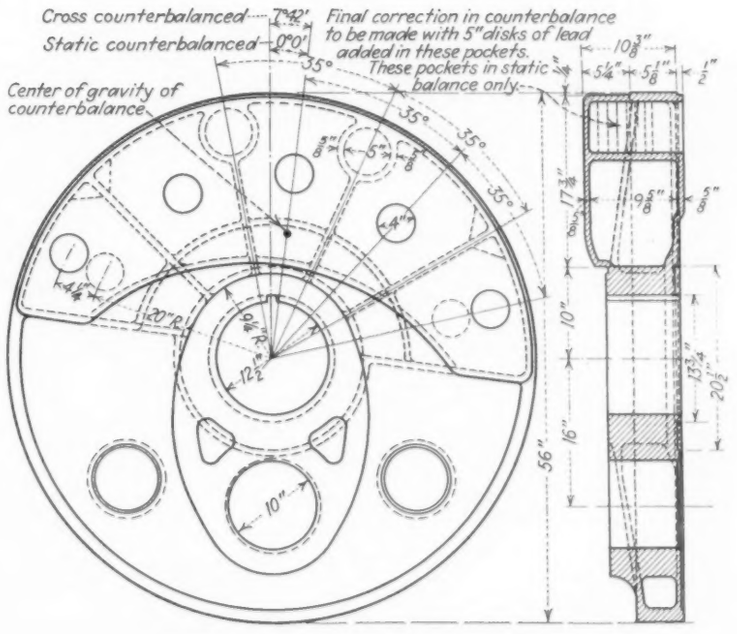
Details of the construction are shown in the accompanying figure. The long end of the "slug" is fastened rigidly to the sector arm *A*, while the cylindrical pin *C* is a drive fit in the sector. Thus, all motion caused by the load on the scale platform must be transmitted through the small leaf spring *S*. Though sufficiently stiff to transmit the steady loads, this spring has sufficient flexibility so that it will absorb any vibrations from the weighing pan to which the arm may be subjected.



Because of the flexible spring connection between the sector and its arm, vibrations cannot be transmitted to the pointer shaft of the scale



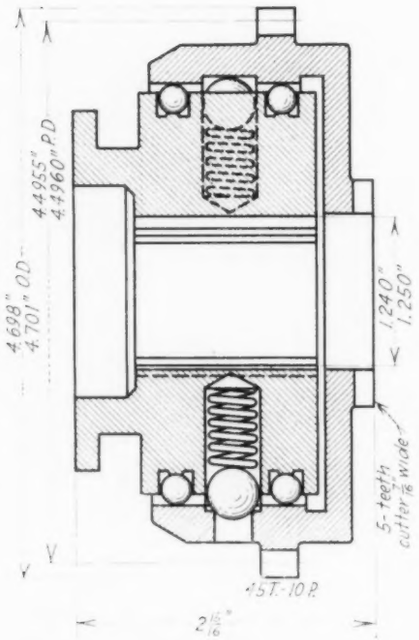
The one-piece body of the Caterpillar-equipped Euclid two-way hydraulic dump wagon is claimed to have more carrying capacity and to be approximately 4 tons lighter than any three-way wagon



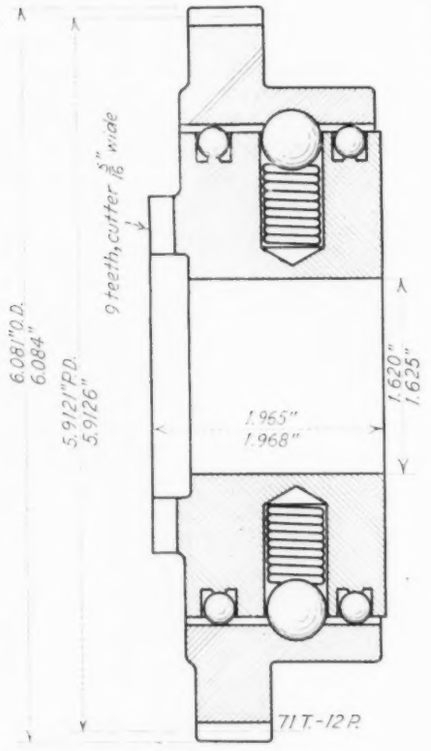
Details of the design of the Scullin Steel Company's double-disk main driving wheel center

Typical Designs

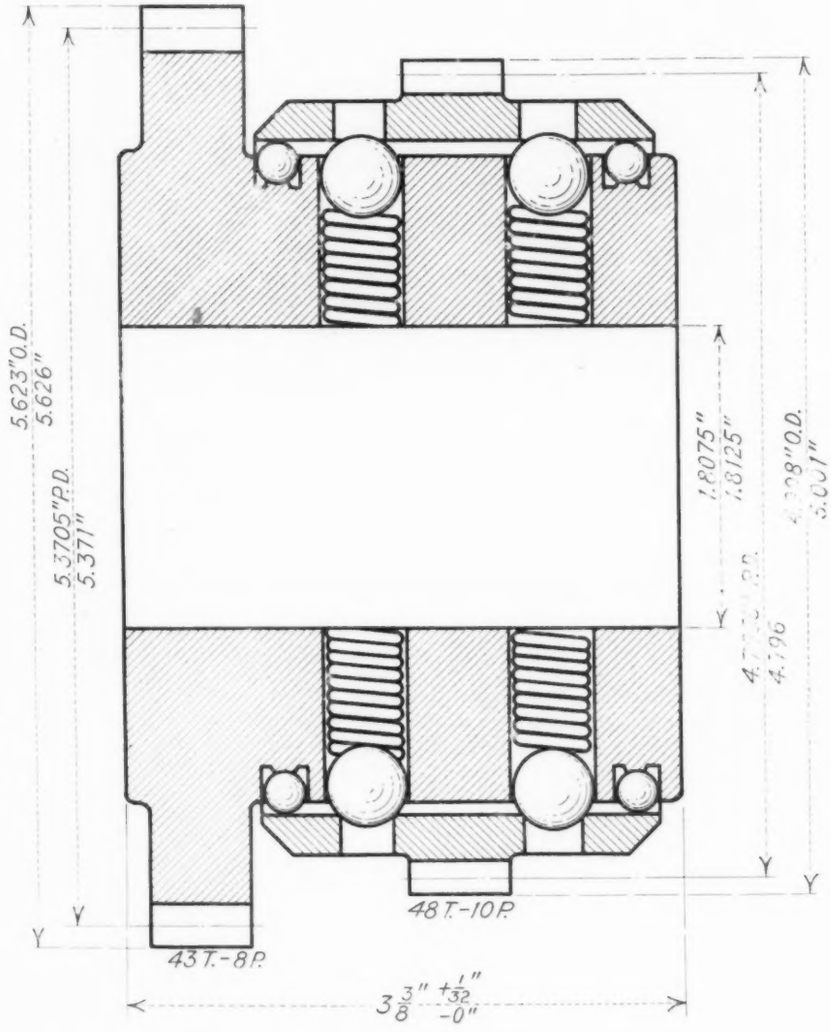
Shear pins are satisfactory only when overloads will be of rare occurrence. If the time lost in replacing broken shear pins is an important consideration, safety gears or their equivalent should be used. The safety-gear designs shown here have been proved by many years in actual service in machine tools



9 springs
13/32" outside diameter
0.092" diam. wire
Load = 814 lb. per in. travel per turn
Test = Load 50 to 60 lb on 20 in. radius lever

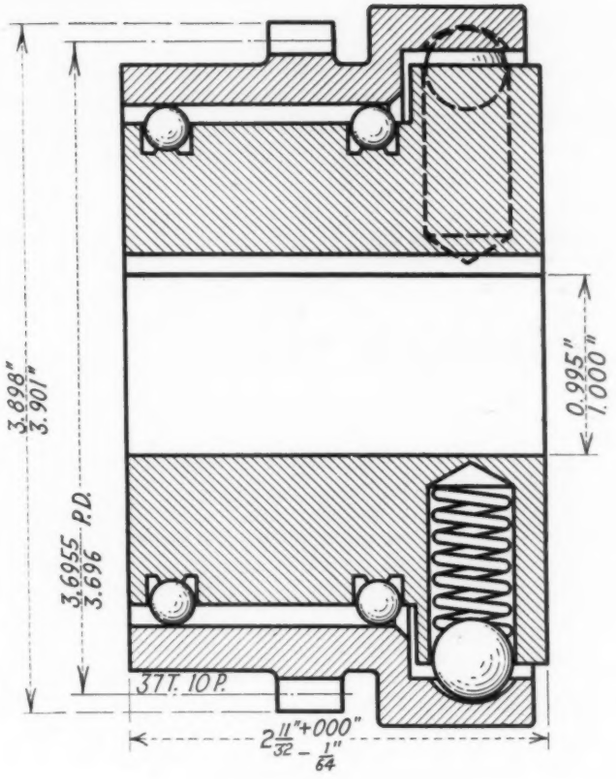


12 springs
31/64" outside diameter
0.109" diam. wire
Load 1,100 lb. per in. travel per turn
Test = Load 65 to 75 lb. on 60 in. radius lever

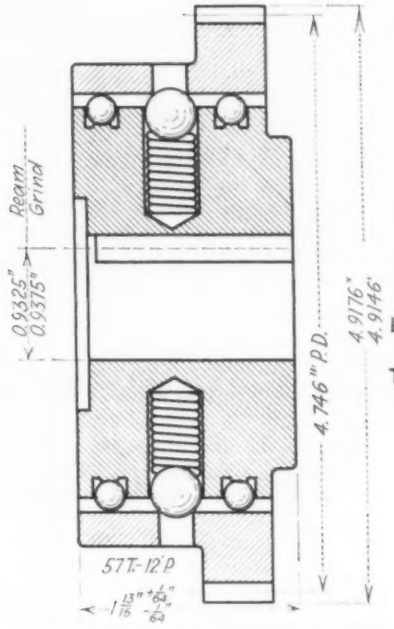


20 springs
31/64" outside diameter
0.109" diam. wire
Load 1,100 lb. per in. travel per turn
Test = Load 65 to 70 lb. on 60 in. radius lever

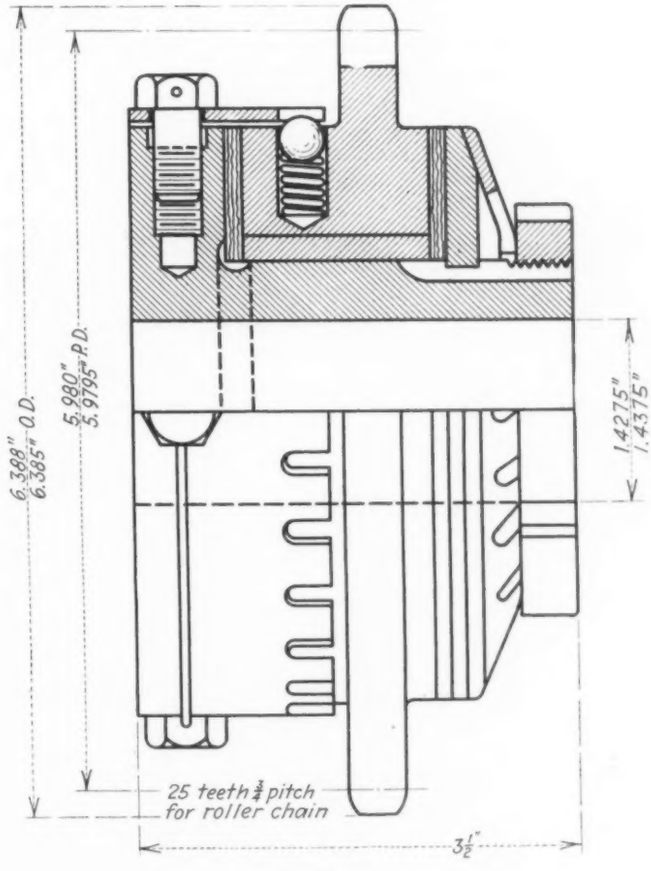
# of Safety Gears



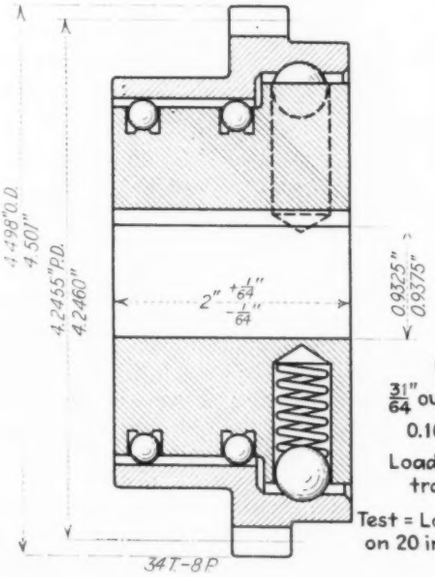
9 springs
31/64" outside diameter
0.109" diam. wire
Load = 1100 lb. per in travel per turn
Test = Load 35 to 40 lb. on 20 in. radius lever



10 springs
7/16" outside diam.
0.080" diam. wire
Load = 259 lb. per in. travel per turn
Test = Load 56 lb. on 18 in. radius lever



2 springs
11/32" outside diameter
0.040" diam. wire
Load = 26 lb. per in. travel per turn, for noise maker only
Test = Load 25 to 28 lb. on a 57 in. radius lever



6 springs
31/64" outside diameter
0.109" diam. wire
Load = 1,100 lb. per in. travel per turn
Test = Load 60 to 65 lb. on 20 in. radius lever

Three more products in a notable series. Whether one approves of their designs or not, these products are making an impression in a market where the average product is finding the toughest kind of sledding. There must be a good reason

Case Histories in Product Design—II

T. J. MALONEY
New Jersey Zinc Company
and
GEORGE SWITZER
Product Designer

▼

The editors of *Product Engineering* have received a letter that openly derides Product Case Histories Nos. 1, 2 and 3 in the February number: "Any engineer could design any one of the three products shown. They are simply the most logical developments of the original conceptions."

So they are. And the designers should be congratulated—not condemned for their logic. The pity is that such logic is not universal.

The ones presented this month impress us as being equally logical, and they are therefore added to our growing collection with the idea that they will be stimulating to engineers and designers in allied lines, and in other lines as well.

While small as radios go, the Air King Midget Radio is a veritable giant in molded plastics

Product Case History No. 4

PRODUCT — Air King Midget Radio.

MANUFACTURER — Air King Products Company.

ENGINEERS — Design engineering staff, Air King Products Company.

ARTISTS—Van Doren & Rideout, Incorporated.

DESCRIPTION — The manufacturers approached Van Doren & Rideout with the idea of creating a small radio in a modern, molded cabinet. They wished to include a clock in the radio for the immediate convenience of finding stations easily and at the proper time. This set was first conceived as a bedroom-boudoir set. Hence, a leeway in choice of colors was desired. Smart, bright shades were preferred. Finally it was decided that a plastic material would be more suitable than wood, and after a detailed study, such a material was chosen. Seventy-five

per cent of the production volume of this new set will be in black with chrome clock bezel, silver dial and special convex clock crystal. The remaining 25 per cent production run will be in six other colors—pastel shades, such as ivory and green. The compactness of this radio is apparent. Its front dimensions are 8½ x 11 in., the same size as a standard business letterhead. The set is available in 4- and 5-tube superheterodyne circuits.

Special engineering problems were involved: (1) While small as radios go, this Midget is a giant in molded pieces. Nevertheless, the large molding is so designed that it can be made by efficient and simple operations. (2) The placing of a clock in such a small space presented a problem. It was difficult to find an electric clock movement sufficiently compact to function properly without interfering with the loud speaker cone. Finally an unusually thin Ingersoll-Waterbury movement was adopted, which perfectly suited the requirements. (3) To permit the inclusion of an electric clock it was necessary to invert the loud speaker. This inversion was found to have the acoustical advantage of directing the sound waves toward the ceiling, where sound absorbing materials are seldom, if ever, used.

A highly significant fact in the evolution of this revolutionary radio has been the complete accord between engineer and artist. Each has recognized his debt to the other. In the beginning, the engineers submitted a chassis and the design was inaugurated on this basis. It was soon apparent, however, that the original chassis did not offer sufficient latitude for the nice proportions desired to make this set distinctive in appearance. At this point, a design, ideal from the artist's standpoint, was evolved. The manufacturer liked it so much that the engineers revised their arrangement to suit the design as closely as possible from a scientific standpoint. A glance at the finished product shows that this union between engineer and artist has been a happy one.

Other factors cropped up from time to time during the evolution of the Midget. The artists had objections to the three round knobs ordinarily found on the face of a radio. Three seemed inadequate to the dignity of the design. Hence, a tuning knob was assembled to the condenser shaft and enlarged to obtain a finer tuning adjustment. The "on and off" switch and volume control knobs assume long, rectangular proportions, repeating the fluted design at the base and blending with the general proportions of the cabinet. In addition, this arrangement enables one to see at a glance whether or not the current is on. The cabinet, in every detail, has been carried out as the designers conceived it. Even the clock bezel, hands and spots indicating the hours are reproduced exactly as originally planned. It was found that regular spacing of hour spots, when the clock dial was elongated to a rectangular shape, gave an unsymmetrical effect. Hence, the spacing was revised to obtain a pleasing visual effect.

SALES RESULTS—No figures are available since this radio has just been placed on the market. It is understood, however, that the manufacturers are at present pushing production in order to keep up with the early orders.

Since the engineering in the Lucas Auto Heaters had been proved sound, the redesigning covered only the exterior shell

Product Case History No. 5

PRODUCT—Lucas Auto Heaters.

MANUFACTURER—Lucas Manufacturing Company.

ENGINEERS — Design Division, Lucas Manufacturing Company, and Doehler Die-Casting Company.

ARTIST—George Graff of Graff-Floraday and Eckel, Incorporated.

DESCRIPTION—In an effort to increase sales and to make the Lucas water heater a harmonious part of any automobile, the front plates were redesigned by the artist and the engineering groups mentioned above. Since the engineering principle of heat dissipation as used in the previous design was fundamentally sound, the redesigning covered only the exterior shell, and that in two ways: (1) newer and simpler design. (2) Substitution of a new type

Sound engineering is the foundation on which all products must be built. It includes an appearance which must not only bespeak the prime requisites of utility and durability but must also arouse a feeling of pride of ownership

of construction and new material for that previously used.

Pictured is one of the thirteen designs. By changing the faceplates from steel stampings to zinc die-castings certain advantages were achieved without increase in production cost. A more rigid construction replaced the easily bent and dented stamped faceplate, and of course the solidity in the design gave better appearance, better plating and better service. The lugs which attach the faceplate to the heater became an integral part, and thereby an assembly operation was eliminated. In addition, using a die-casting gave the artist an opportunity for a wider selection of finishes and modern, simplified appearance.

SALES RESULTS — Sales during the current season have increased 60 per cent over the 1931-32 season even though temperatures throughout the winter were markedly warmer in most vicinities.

PROBABLE REASONS FOR SUCCESS—Increased appeal to the public through variety in design, there being 13 models. More permanent finish because of rust-proof zinc base die-castings. A more substantial appearing unit than the old type heater.

Product Case History No. 6

PRODUCT—The Chronolog.

MANUFACTURER—The National Acme Company.

INVENTOR — Max Jeffrey, The National Acme Company.

ENGINEERS—Design Division of The National Acme Company and the Graybar Electric Company.

DESCRIPTION—The Chronolog is a work recording device designed to give the operator, foreman, superintendent and general manager a constant running picture of what's being done by each production machine. It gives an accurate record of men and machines—which ones are productive, which are non-productive, and what to do to remedy the situation. The Chronolog actually allows each operator to become his own time-study man, and eliminates much of the discontent engendered by the human factor in appraising production.

The exterior design is purely functional, it having been developed to house the operating mechanism and to offer utmost convenience to the operator. As is so frequently the case where the designer does not strive for any artistic effect whatever, he achieves an accurate if not wholly an aesthetic appearance.

SALES RESULTS—Good. Introduced during 1932, the Chronolog met instant acceptance. In one plant it proved such a profitable investment on a stub lathe, a hand milling machine and a broaching machine working on automobile connecting rod bearings, that enough more were ordered to complete the installation for one entire department. The instrument has already entered the widely divergent fields of press forming, thread rolling, blooming mills, electric welding, electric batteries, glass blowing and various general machine shop operations.

PROBABLE REASONS FOR SUCCESS — A well-conceived, well designed product intelligently marketed in virtually uncultivated fields.

The Chronolog allows a machine operator to become his own time-study man, thus eliminating much of the discontent engendered by time studies

Worm Gear Contact Errata

Attention is called to the fact that in Fig. 4*E*, on page 43 of the January *Product Engineering*, the lettering of the points on the *X*, *Y* and *Z* curves does not correspond to that on the other views. At the intersections of plane 2 with curves *X*, *Y* and *Z* the letters should read *c*, *d* and *e* respectively. Similarly for the intersections of curves *X* and *Y* with plane 2′ the letters should read *g* and *f* respectively, with the letter *b* in Fig. 4*D* changed to *f*. The addition of these letters serves to clarify the relationship of the different views.

Referring to Fig. 7, on page 45, the angle θ should be the complement of the angle as labeled, that is, the angle should be from the vertical.

COMMUNICATION and COMMENT

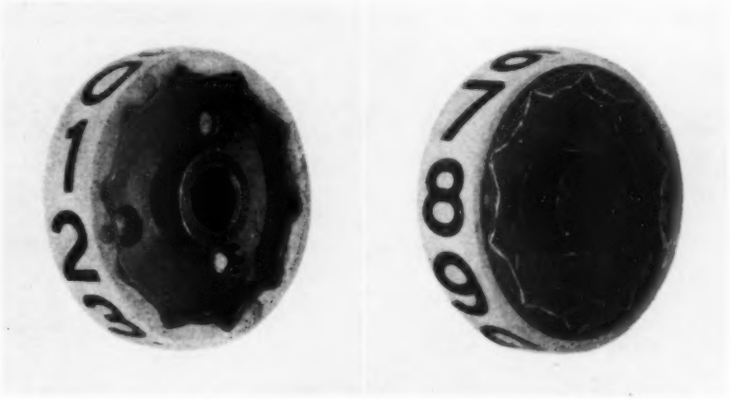
Redesign of a Small Assembly

FRED R. LUFKIN
Elgin, Ill.

Much can be accomplished in redesigning even relatively small units by changing to a different type of construction. Usually such a design problem requires consideration of the unit as a whole rather than a separate study of each individual part.

In the original assembly of the numbering wheel shown in the illustration the bearing hub was a separate part machined from brass rod. The teeth for the ratchet wheel were formed in a light, soft brass strip and this strip was pressed into corresponding tooth formations, made in the celluloid ring which carried the numbers. While this was the accepted method of making parts of this type, it involved considerable work in the machine shop and much time-consuming assembly work. Moreover, the brass teeth would not stand up for long periods under the continuous wearing of the operating ratchet.

These difficulties were overcome by redesigning the wheel, as shown, and incorporating in a single part the teeth and the bearing hub. This single part is die-cast in aluminum bronze, a metal alloy which has excellent wearing qualities and an average ultimate strength of 85,000 lb. per sq.in. Little machining has to be done on the die-cast part as the teeth are formed completely in the die. The machining of the celluloid ring is likewise reduced and simplified. In assembling, the one new part replaces two old parts and the task of obtaining concentricity between the bearing and the outer periphery of the celluloid ring is much easier than in the original design. Tests also indicate that the aluminum bronze teeth show no appreciable wear over long periods.



To the left, the original design of the numbering view, with hub a screw-machine part, and ratchet wheel formed out of soft brass strip and pressed into the celluloid ring. The redesigned unit incorporates in a single part the teeth and the bearing hub

Observations on Poisson's Ratio

Commenting upon the observations of Professor Dana concerning the possible relationship between the density of a metal and the value of Poisson's ratio, as published in the February number of *Product Engineering,* W. H. Clapp, of the California Institute of Technology, gives the following data and comments in "Machine Design Clearing House," a leaflet circulated among teachers of machine design.

Metal	Weight Cu.In.	Poisson's Ratio
Electron Metal.....	0.068	0.26
Duralumin.....	0.098	0.275
Armco Iron, hot rolled	0.280	0.197
Medium Carbon Steel, annealed.....	0.275	0.241
Stainless Steel, KA2..	0.278	0.365

Quoting Professor Clapp: "From these data it would seem that there is no apparent connection between the density and Poisson's ratio. I find no value for Poisson's ratio for such heavy metals as gold or platinum, but it would be apparent that if these were to increase in the order of density they would be considerably in excess of the maximum possible value of this ratio, which is 0.50.

"Poisson's ratio certainly does have to do with the relation existing between the atomic bounds. It is well known that metals having a large atomic volume are more easily compressible, have a low elastic modulus, high coefficient of expansion, and relatively low melting temperature, while metals having a small atomic volume have on the whole quite the reverse characteristics."

Commenting on the same question, Dr. A. Nadai, of the Westinghouse Electric & Manufacturing Company, states:

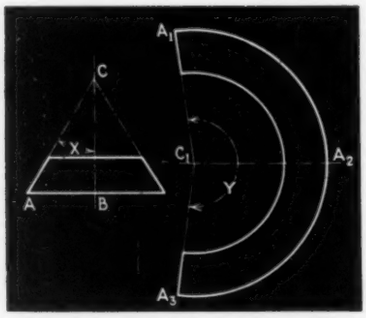
"Referring to the question whether a relation exists between density and Poisson's ratio, it seems that Professor Dana's statements generalize too far. It is true that certain porous materials show low values of Poisson's ratio. This is, for example, the case for concrete or cast iron. However, the low figures for Poisson's ratio are probably not due to the com-

paratively small density of the material but more to the presence of holes and pores. These latter will close up under compression. Thus the material will show less lateral deformation. But to conclude from this fact that Poisson's ratio must be greater for lead than for steel, is hardly correct. For cast iron Poisson's ratio will probably be variable with stress. For this reason it is not right to record an arbitrarily determined Poisson's ratio for cast iron and to compare it with the ratio for such compact and solid materials as steel or copper. Before anything is more definitely said about the relation between Poisson's ratio and the weight per cubic unit, it would be necessary to check carefully by what testing methods the Poisson's ratios have been obtained for such very differently behaving materials as cast iron and lead."

Developing the Cone

I. COHEN
London, England

In the usual procedure of obtaining the development of a cone or a frustrum thereof, it is customary to step off the circumference of the base circle. In the accompanying figure the arc $A_1A_2A_3$ is drawn with a radius A_1C_1 equal to the slant height AC of the cone. In the usual procedure, the base circle of radius AB is then drawn and its circumference



Instead of stepping off the arc $A_1A_2A_3$ to equal the circumference of the base circle of radius AB, the angle Y can be calculated by simple proportion

stepped off on the arc of the development, thereby establishing the points A_1 and A_3.

In order to eliminate the tediousness and the inaccuracy of this method of construction, the angle Y can be calculated by the following formula:

$$Angle\ Y = 360 \times \frac{AB}{AC}\ deg.$$

With this angle determined, all of the other dimensions of the development can be calculated accurately.

As the ratio AB/AC is the sine of the angle X, the angle Y can be tabulated for different values of angle X, the semi-apex angle of the cone.

Stresses in the Lifting Hasp

To the Editor:

In the following solution of the problem submitted by F. B. Faulkner, as published on page 502 of the December, 1932, *Product Engineering*, no calculations or methods for computing the deflection are included. On account of the short length of the beam and the small size of the specimen, the deflection of the part up until the elastic limit is reached will be but slight.

The greatest fiber stress will be at each side in the straight portion of the beam. These stresses can be determined by the formula for a curved beam in the following manner:

Stress due to tension only

$$f_1 = P/A$$

Stress due to bending only

$$f_2 = \frac{M}{r\,(B - A)}\left(\frac{B}{A} - \frac{r}{r - y}\right)$$

Total stress in tension

$$f = f_1 + f_2$$

P = load in lb.
A = cross-section area
= $1\frac{1}{4} \times \frac{3}{8} = 0.4687$ sq.in.
r = mean radius of beam = $2\frac{7}{8}$ in.
y = distance from center of beam to outside fibre = $\frac{5}{8}$ in.

$$B = rb \log_e \frac{2r + h}{2r - h}$$

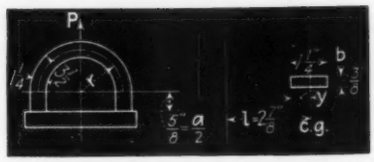
b = width of beam = $\frac{3}{8}$ in.
h = depth of beam = $1\frac{1}{4}$ in.
l = moment arm = $2\frac{7}{8}$ in.
$f_1 = P/0.4687 = 2.14\ P$
$B = 2.875 \times 0.375 \log_e$

$$\frac{5.75 + 1.25}{5.75 - 1.25} = 0.47632$$

$$f_2 = \frac{2.875\ P}{2.875\ (0.47632 - 0.46875)\left(\dfrac{0.47632}{0.46875} - \dfrac{2.875}{2.875 - 0.625}\right)}$$

$$= 34.6\ P$$

$$f = (2.14 + 34.6)\ P = 36.7\ P$$



The load of 1,450 lb. is distributed between both sides, therefore:

P = 725 lb.

Hence

= 36.7 P = 36.7 × 725 = 26,600 lb. per sq.in. tension

Load at yield point is equal to:

$P = f/36.7$

When f = yield point = 12,300 lb. per sq.in.

P = 12,300/36.7 = 335 lb. on each side

335×2 = 670 lb. total load at yield point

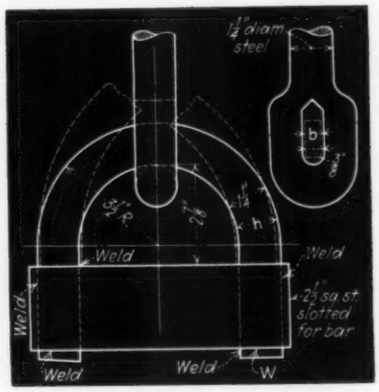
Likewise to compute breaking load

$P = f/36.7$ = 35,650/36.7 = 971 lb.

971×2 = 1,940 lb. total breaking load

—NORMAN M. WICKSTRAND
Meriden, Conn.

It is interesting and startling to compare the calculated results with those obtained by actual tension test. A test load of 20,000 lb. produced a



Design of lifting eye for which load and stress calculations are given in the text. The dotted lines show how failure took place at a load of 33,400 lb.

deflection of $\frac{1}{64}$ in. Definite yielding took place at a total load of 24,300 lb., and the link broke as shown in the accompanying sketch at a load of 53,400 lb. Details as to how the yield load was identified are not available. However, it is safe to assume that definite yielding of the structure was not perceptible until after the yield point of the material had been exceeded. This naturally follows from

the fact that the maximum stresses are largely the result of bending moments rather than tensile stresses.

Some of those who presented a solution took the pains to state specifically that the stress and deflection formulas would not apply beyond the elastic limit, and it is this factor that accounts for the wide divergence between the calculated results and the test results. It is also interesting to note that the calculated results are well on the side of safety, giving in each instance a factor of safety higher than what would probably be required.

One fact definitely bears out the supposition that the "yield point" of the structure as given by the test was at a load that created a stress far beyond the yield point of the material, given as 12,300 lb. per sq.in. The cross-sectional area of the $1\frac{1}{4}$ x $\frac{3}{4}$ in. link being 0.9375 sq.in., it follows that if the metal was solely in tension the structure would yield at a load of slightly less than 23,000 lb. But in addition to the straight tensile stresses, there are the stresses resulting from the bending moments. These last are considerably greater than the tensile stresses. From this it is evident that as the yield load of 24,300 lb. as determined by the test, the material was under a stress considerably beyond the elastic limit.

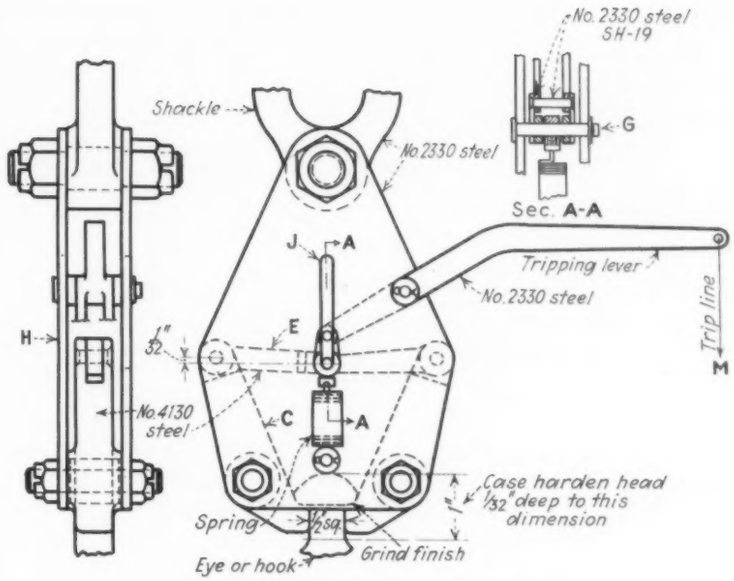
More than any other thing, this problem illustrates the futility of attempting to calculate the ultimate strength of such constructions.

Quick Release Mechanism

GEORGE A. FRIES
Philadelphia, Pa.

Quick release mechanisms have numerous applications. Although the design shown here operates as a tripping device for a quick release hook, mechanical principles involved undoubtedly have many other applications. Fundamentally, it is a toggle-type mechanism featured by the fact that the greater the load the more effective the toggle.

The hook is suspended from the shackle, and the load or work is supported by the latch which is machined to fit the fingers *C*. The fingers *C* are pivoted about a pin. Assembled to the fingers are the arms *E*, pinned at one end and joined at the other by the sliding pin *G*. Inclosing the entire unit are the side plates *H* containing the slot *J* for guiding the pin *G* in a vertical movement when the hook release. The helical spring returns the arms to the bottom position after they have been released.



Simple quick-release toggle mechanism as designed for tripping a lifting hook

To trip the hook, the tripping lever is pulled by the cable *M* until the arms *E* pass their horizontal center line. The toggle effect is then broken, thereby releasing the load.

Methods of Solving a Problem in Triangles

In the January number Francis W. Shaw presented the problem of determining the unknown sides of the triangles *A*, *B* and *C*, the condition being that the area of triangle *A* is to be equal to the sum of the areas of *B* and *C*. Here are several different solutions to this simple problem, indicating a wide range in the method of attack. Perhaps some of these solutions are open to criticism but they are given here as presented by the readers in order to show the widely different methods of approach. The first solution is that of Mr. Shaw, who presented the problem.

To the Editor:

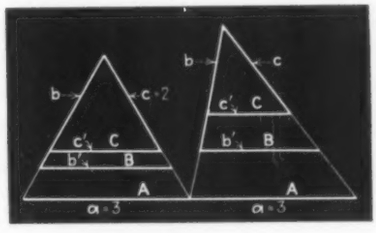
A rough layout as in the accompanying figure showed that the triangles could be acute and approximately equilateral. They were assumed to be equilateral for the sake of analysis.

Now, if the area of *A* be equal to the areas of *B* and *C* combined, it follows that $a^2 = b'^2 + c'^2$. But b' and c' are respectively equal to b and c when the triangles are equilateral and then all the conditions are fulfilled. It is obvious that b or b' is equal to the square root of $a^2 - c^2$, that is:

$$b = \sqrt{3^2 - 2^2} = \sqrt{5} = 2.236$$

One solution, then, is to make the triangles equilateral, each having sides of 3 in., 2.236 in., and 2 in. Is any other solution possible?

Let the larger diagram of the accompanying figure represent any other three similar triangles in which $a^2 = b^2 + c^2$. In the figure, *a*, *b* and



c are indicated by the heavier lines. Then, according to plane geometry, if $A = B + C$ in area, *a*, *b* and *c* must be the homologous sides of three similar triangles. But they are not the

homologous sides, hence A is not equal to $B + C$, and the given conditions are not fulfilled. Therefore, as a little study will now reveal, the triangles can only be equilateral.

—FRANCIS W. SHAW
England

To the Editor:

Since the three triangles are similar, triangles B and C can be imposed on triangle A as shown in the accompanying figure, and the whole divided into small equal triangles such that:

Area A = 25 small triangles
B = 16 small triangles
C = 9 small triangles

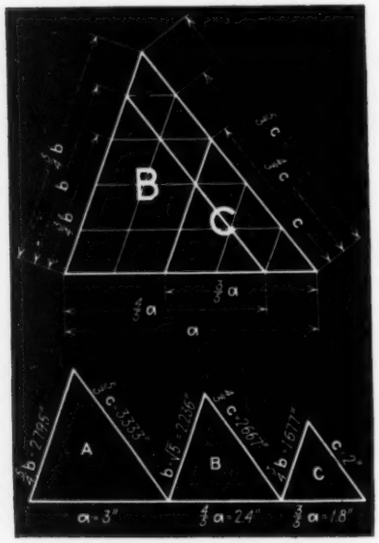
Area A must equal area B plus C

The values of all sides can then be set algebraically by inspection.

And since

$$b = \sqrt{A^2 - C^2} = \sqrt{3^2 - 2^2} = \sqrt{5},$$

it is a simple matter to give the values for the sides of all three triangles, as shown in the figures. Only one set of positive values is possible.



—J. F. STROTT
San Francisco, Calif.

To the Editor:

One solution to the problem is based on the following theorem in geometry.

If on the three sides of a right triangle as homologous sides, similar polygons of n sides be constructed, the area of the polygon on the hypotenuse equals the sum of the areas of the polygons on the other two sides.

In the problem proposed we have the conditions shown in the accompanying figures. Let A, B and C equal the areas of the required similar triangles. By the conditions

$$A = B + C$$
$$a^2 = b^2 + c^2$$
$$\frac{B}{A} = \frac{b^2}{a^2}$$
$$\frac{C}{A} = \frac{c^2}{a^2}$$

By addition we get:

$$\frac{B + C}{A} = \frac{b^2 + c^2}{a^2} = 1$$

Whence

$$A = B + C$$

The triangles A, B and C are equilateral, therefore

$$A = \frac{a^2\sqrt{3}}{4}$$

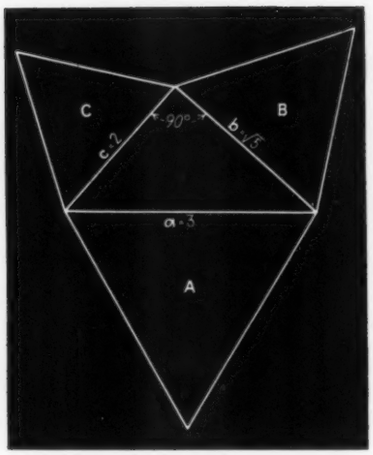
$$B = \frac{b^2\sqrt{3}}{4}$$

$$C = \frac{c^2\sqrt{3}}{4}$$

Combining the above expressions for the areas, we get:

$$\frac{B + C}{A} = \frac{b^2 + c^2}{a^2}$$

Therefore the required similar triangles A, B, and C are equilateral with sides equal to 2, 3, and $\sqrt{5}$ respectively. —WILLIAM W. JOHNSON
Cleveland, Ohio



DEFLECTIONS

SODIUM-PROOF GLASS

The new sodium vapor lamp has an efficiency of 70 per cent, which is three to four times neon and about six times the efficiency of a tungsten filament lamp. But up to now the main difficulty in commercializing and adapting such a lamp has been the inability of ordinary glass to resist the attack of sodium. Now comes a report that Jena Glass Works, Germany, has perfected a glass which not only resists the attack of sodium, but withstands temperatures up to 300 deg. C., at which point sodium vaporizes. It is also understood that this glass is now available in the United States.

STITCHED PIES

Do you remember the old gag of the bashful church usher who said, "This pie is occupewed, may I sew you to a sheet?" It has a modern and very practical application. Bakers' pies are now placed on paper plates, covered with a celophane sheet, and sewed in by means of a stitching machine that staples cover and plate securely together around the edge. Incidentally, there is a hieroglyphic that informs the sophisticated dispenser, but not the customer, how old the pie is.

USING THE RIGHT MATERIAL WRONGLY

In reporting experiences in the use of rubber to eliminate noise and vibration, the superintendent of equipment of a street railway stated, "We applied ½ in. rubber pads of full size between the body center bearing and the body bolster on one of our cars. We also placed rubber pads beneath the compressor support brackets on two cars. Although there was some benefit derived from this installation, it was so slight that we do not believe it would justify the additional expense."

Engineers who have had experience in rubber mountings will be inclined to agree. Unless the mountings are properly designed, good results cannot be expected. Merely a rubber pad beneath a supporting bracket sounds like perfunctory design. To use the right material in the wrong way is like getting into the right church but the wrong pew.

· NEWS ·

Speed, Vibration and Replaceable Units Get Greatest Attention

In the product development survey that appeared in *Product Engineering* last November, a tabulation on page 441 of that issue listed the factors emphasized in the design of manufacturing equipment for non-metal products, the greater portion being textile machinery. Higher speeds of operation, more easily replaceable units and the minimizing of vibrations were given as the three factors receiving greatest attention.

The reliability of the above mentioned report was reflected in the exhibits at the Knitwear Industrial Exposition held at Grand Central Palace, New York, N. Y., Feb. 13-17. In an improved circular knitting machine, the designers adopted a unit construction for the wall of the needle-cylinder. Previously this was a thin-walled cylinder with longitudinal straight grooves in the outer surface for the needles. It is not uncommon for the cylinder wall to be damaged. In the new design, the cylinder is made up of interlocking wall sections, one for each needle groove. Damaged sections are readily replaced.

Along this same line, another engineer has the needle cylinder made of hardened steel. The evident intent is to prevent damage rather than providing for repairs to be made more easily.

In the operation of circular knitting machines it sometimes happens that a butt drops out and falls into the cylinder. To get the butt out, it is usually necessary to disassemble the machine. One designer solved this problem by simply opening the bottom of the needle cylinder. Anything that drops into the cylinder falls through to the floor.

Flat knitting machines of at least one make now use duralumin for the carriage and other reciprocating parts. In another effort to minimize vibration, of importance to prevent the dropping of stitches, high-carbon steel is being used for the carrier bars. Steadily increasing operating speeds compel greater attention to the factors affecting vibrations.

Other new features of general interest include oil-proof rubber covering for the take-up rolls that draw the cloth away from the needles, V-belt drives, and geared hand-drives. This last is to make it easier for the operator to turn the circular knitting machine with the hand crank when adjustments are to be made.

For the first time there was exhibited a "links and links" circular knitting machine for knitting purl stitch. The significance is that up to this time such knitting was done only on flat machines using reciprocating motions. This development emphasizes the attention that is being given to getting away from reciprocating motions by the substitution of rotary motion, thereby circumventing many problems of vibration, and permitting higher production. It also illustrates how a single development can affect a whole industry, it being reported that the showing of this machine created tremendous interest.

Re-Engineering for Economical Manufacture

All phases of the problem of engineering new products will be discussed at the industrial conference to be held at Case School of Applied Science in Cleveland, Ohio, Mar. 22-24. "Production Development—Whither Bound?" is the title of a paper to be presented by E. L. Shaner, editor of *Steel*. R. E. Hellmund, chief electrical engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., will speak on the "Redesign of the Product to Increase Appeal to the Purchaser." "Developments in Manufacturing Processes" by D. Levinger, engineer of manufacturing, Western Electric Co., deals with the reduction of costs through the use of suitable materials as well as by improvements in production methods. Other papers that deal most directly with the work of the designing engineer include: "Metal Forming to Eliminate Machining," by Charles D. Harmon, The National Machinery Co., Tiffin, Ohio; "The Place of Stampings in the Product," J. K. Olsen, chief draftsman, Stewart Warner Corp., Chicago; "Influence of Welding on Design and Production" by R. E. Kinkead, consulting engineering of Cleveland, Ohio.

Of the above speakers, R. E. Hellmund, J. K. Olsen, and R. E. Kinkead are well known to our readers as authors of articles that have appeared in *Product Engineering*.

Materials Symposium Creates Lively Interest

Proposed specifications for chromium-nickel alloy castings for valves, strainers, pumps and fittings used in sulphite processing created a lively discussion at the annual meeting of the Technical Association of the Pulp and Paper Industry, Feb. 13-16. The chemical composition of the proposed alloy steel is:

	Per Cent
Chromium	20
Nickel	9
Carbon	less than 1/100 of chromium content
Sulphur	0.05 max.
Phosphorus	0.05 max.
Silicon	Not specified
Manganese	Not specified
Iron	Balance

At the option of the purchaser, from 2 to 4 per cent molybdenum may be specified. The complete specifications include heat treatment, tests, pickling, workmanship, finish and other properties.

According to a paper by W. E. Jorning and R. S. Archer, engineers of the A. O. Smith Company, welding offers the only successful method for lining plain carbon steel with stainless steel. They also discussed stainless-clad steel sheets, and reported that three small lined digesters have been in operation for more than

a year and have not shown any deterioration. The small difficulties encountered in stainless linings are insignificant when compared with the ceramic linings. The latter require continuous repairing to keep them in shape. The authors of the paper also reported satisfactory service from steel linings in the oil industry and further adoptions of stainless steel linings in the chemical industry. Another investigator, W. C. Johnson, of the Plykrome Corporation, reported that composite stainless and low-carbon steel sheets can be readily arc welded.

A.S.A. Standards

A revision of the American Tentative Standard for Annular Ball Bearings, Single Row Type (B3a-1930) was approved by the American Standards Association in January as American Standard, with the designation B3.1-1933.

This revision consists of a change from 0.4 and 1.0 mm. to 0.6 and 1.5 mm., respectively, in the dimensions *r* and *H* of the light type bearing Number 39 (*r* designates the maximum radius of the fillet of a shaft or housing, and *H*, the minimum height of the shoulder on a shaft). The revision also includes the addition of the Separable (Open) Type Ball Bearings, and of the Angular Contact Type Ball Bearings in the light, medium, and heavy series.

"American Recommended Practice for Engineering and Scientific Charts for Lantern Slides (Z15.1-1932)" has also been approved. The standards will provide rules for widths of lines, lettering, and symbols designed to assure greatest legibility. In developing the standard, attention was directed chiefly to the most common variety of engineering and scientific charts, namely, line charts which show the relationship between two variable quantities.

The Cost of Friction

In a series of laboratory tests conducted by H. F. Williams, superintendent of equipment, Department of Street Railways, Detroit, the energy required to maintain a given temperature rise in a bearing was measured.

Calculated on the results of these tests, a 3¾x7-in. journal dissipates energy at the rate of 1.562 watts per deg. F. rise in temperature. For a double-truck car operating ten hours per day, and with current costing $0.01 per kw.-hr., this cost is practically ⅛ per cent per day. These figures pertain to babbitt-lined brass bearings used on street cars.

Dodge to Represent Industrial Artists

William W. Dodge has resigned as managing editor of *Product Engineering* to act as adviser on product design and as eastern business representative for a group of outstanding industrial artists and designers: Joseph Sinel, Lucian Bernhard and Helen Dryden. All three artists have achieved international recognition in the field of product design and redesign, packaging, posters, trade marks and other forms of industrial art.

Headquarters have been established in the McGraw-Hill Building, 330 West 42nd Street, New York, N. Y., in addition to which each artist will maintain his individual studio.

Mr. Dodge, a graduate of Cornell University, was for several years managing editor of *American Machinist*. Before joining the McGraw-Hill organization, he was district manager for the C. O. Bartlett & Snow Company, vice-president of Dodge Manufacturing Company and general manager of National Veneer Products Company.

"New Materials—New Products—New Uses"

Under the above name and style, an exhibition sponsored by The National Alliance of Art and Industry, 65 E. 56th St., New York, N. Y., came to a close Feb. 15. In it were shown 101 exhibits of manufactured and handicraft products ranging from cosmetic containers to air-conditioners, together with several items made of comparatively new materials. A large proportion of the exhibits have already been described in the various departments of *Product Engineering*.

According to the number of inquiries registered at the exhibition information desk, the "hit of the show" was a group of objects made of aluminum, colored in a variety of hues by the anodic process. Next in the order of interest was an exhibit of woods colored in the growing tree by a secret process of inoculation whereby growth rings become green, blue, lavender and other colors.

MEETINGS

American Society for Testing Materials—Annual Meeting, Chicago, Ill., June 26-30. New York Regional Meeting, Mar. 8. Group meetings of committees, New York, N. Y., Mar. 6-10. R. E. Hess, assistant secretary, 1315 Spruce St., Philadelphia, Pa.

American Welding Society—Annual Meeting, Apr. 27-28, New York, N. Y. Miss M. M. Kelly, secretary, 29 W. 39th St., New York, N. Y.

Case School of Applied Science and the Cleveland Engineering Society — Joint conference on "Re-Engineering for Economical Manufacture," Cleveland, O., Mar. 22-24.

Gray Iron Institute — Annual Meeting, Cleveland, Ohio, Mar. 22. Headquarters at Hotel Cleveland. Arthur J. Tuscany, manager, 4300 Euclid Ave., Cleveland, Ohio.

EXHIBITIONS

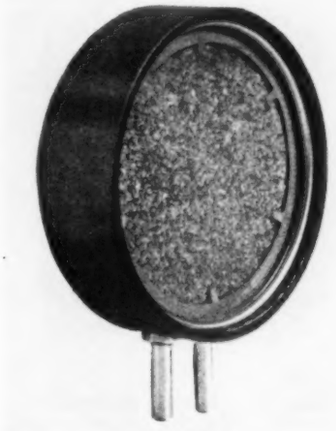
American Management Association — Third Annual Packaging, Packing and Shipping Exposition, Conference and Clinic, Hotel Pennsylvania, New York, N. Y., Mar. 7-10.

American Oil Burner Association —10th National Oil Burner Show, Hotel Stevens, Chicago, Ill., June 12-16.

NEW MATERIALS and PARTS

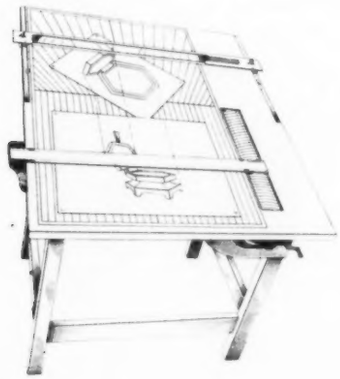
Rhamstine "Electronic" Cell

Is a self-generating type of photo-electric cell for general application and service in laboratory, commercial and industrial fields. Of the dry disk type, it transforms light energy directly into electrical energy without aid of batteries or other source of emf. Cell measures 2⅜ in. diameter and 1 in. thick. Equipped with two connection prongs which fit standard UX radio tube socket. J. Thos. Rhamstine, 511 E. Woodbridge, Detroit, Mich.



Calibron Perspective Machine

Device consists of a perspective drawing mechanism mounted on a specially constructed drafting table. The visible portion of this mechanism consists of a cylinder and sliding straight-edge mechanically connected. Using specially ruled paper and locating the perspective position of each point by three simple operations, and then connecting the points, a true perspective is obtained. It is claimed no skill other than that possessed by all good draftsmen is required. Calibron Products, Inc., West Orange, N. J.

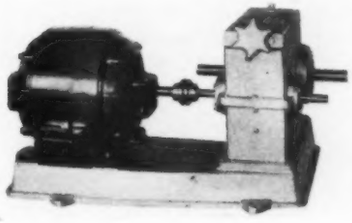


Plioform

A rubber base product from which kitchen appliances, dishes and a wide range of molded goods can be manufactured at low cost. Available in large variety of colors, and types producing attractive mottled and opalescent effects. Tasteless, odorless and resistant to scratches. Also "unbreakable" in same sense as other high-grade plastics. Contains no sulphur and requires no vulcanization. Claimed to have good electrical properties. Available as resin or compound to manufacturers in molded goods field. Goodyear Tire & Rubber Co., Akron, Ohio.

Lenney Variable-Speed Transmission

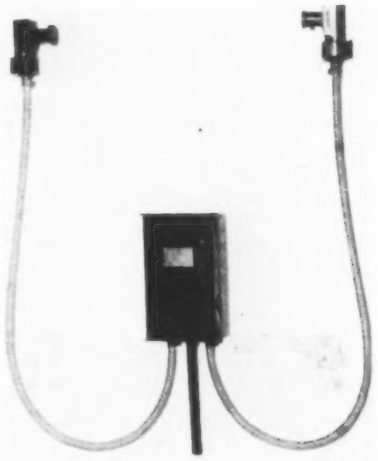
With infinitely adjustable speed control. Claimed to give any speed whatever, even to slightest fraction of a



revolution in speed increase or decrease, between predetermined high and low limits. Speeds obtainable: 1150 r.p.m. input, 10 to 100 r.p.m. infinitely variable; 1750 r.p.m. input, 15 to 150 r.p.m. infinitely variable. Unit is irreversible, but can be built to run in either direction. Now ready for market in sizes up to 1 hp. The Lenney Machine & Mfg. Co., Warren, Ohio.

Westinghouse "Photo-Troller"

Designed as a rugged industrial device which can be actuated by phototube or by delicate contacts carrying only a few microamperes. Especially



adapted to applications such as counting, limit switch, door opening, automatic weighing, etc. Phototube or sensitive contact operates a sturdy grid glow tube directly which in turn closes contactor capable of initiating any desired operation. Thus, delicate intermediate relays are eliminated. Comes assembled in sheet metal cabinet with convenient door and knockouts. Is available for any commercial voltage or frequency except d.c. Photo-tube and light source housings are of cast aluminum. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

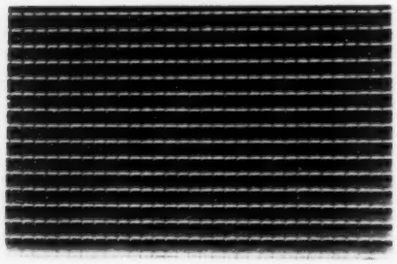
Ideal Pipe-Ventilated Motor

Especially designed for services where motor is exposed to excessive humidity, high temperature, abrasive particles, or lint. Also recommended for locations involving fire hazards from inflammable dust or explosive vapors. This totally inclosed polyphase squirrel-

cage induction motor is ventilated by large centrifugal fan which draws cool air in at one end through suitable pipe and discharges warm air out of other end. Available in ratings from 1 to 200 hp. in both squirrel-cage and slip-ring induction types. In all voltages up to 230. Ideal Electric & Mfg. Co., Mansfield, Ohio.

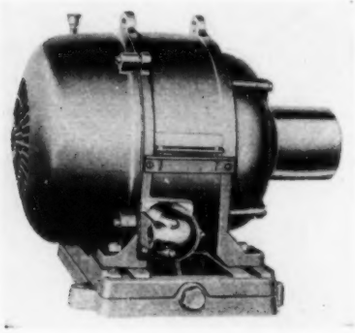
Houghton Vim Tred Leather Belt

Is provided with "non-skid" surface produced by pressing down or indenting part of surface of belt. Claimed to concentrate pressure between belt and pulley on ribbed tread and consequently to increase gripping power. E. F. Houghton & Co., Third, American & Somerset Sts., Philadelphia, Pa.



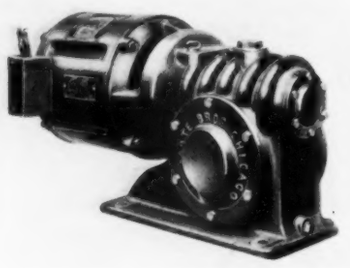
Marble-Card Fan Seal Type Motors

In sizes ranging from 2 hp. at 900 r.p.m., to 30 hp. at 1,800 r.p.m. Claimed that new type motor is self-cooling, self-cleaning, self-protecting and being entirely inclosed is free from such hazards as dust, dampness and fumes. No special motor housing or ventilating system required. May be operated out-of-doors, subject to rain and snow. Marble-Card Electric Co., Gladstone, Mich.



Foote Bros. IXL Powered Gears

Available in two styles; the radiating worm gear type and the helical gear type. Worm gear line covers ratio ranges from 4 to 1, to 60 to 1 single reduction style and up to 3,600 to 1 in double reduction worm type. Radiating case design results in greatly increased heat radiating capacity said to materially increase continuous load ratings. Helical type made in single and double



and triple reduction ratios—providing range of output speed from 4 r.p.m. to 850 r.p.m. and capacities up to 150 hp. Anti-friction bearings are standard, but sleeve bearings may be supplied at option where extreme quietness of operation is essential. Available with motors ranging from ½ to 150 hp. Abel Davis and Franklin H. Fowler, receivers in equity for Foote Bros. Gear & Machine Co., 5301 S. Western Blvd., Chicago, Ill.

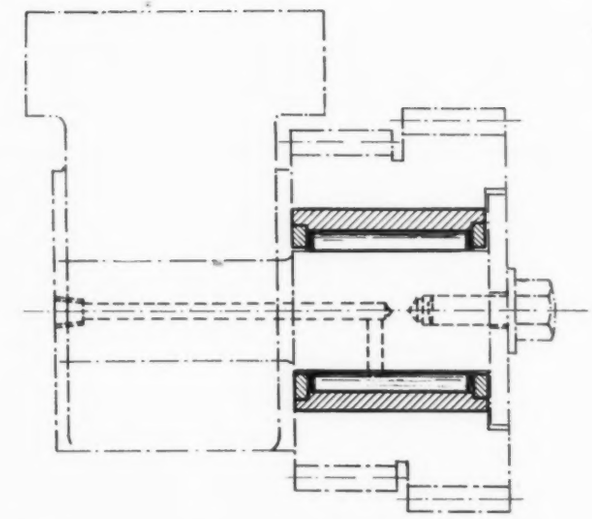
Bantam "Needle" Type Roller Bearings

Are now in volume production in sizes ranging from 0.0625 in. diameter to 0.1880 in. diameter and with tolerances of ±0.0001 in. to ±0.0002 in. Typical applications are automotive universal joints, diesel engine piston pins and crankshafts, high-speed marine engines, printing presses, gears, pumps, transmissions, small rolling mills, high-speed drills and tools, automotive brakes, rocker arms and other installations where very limited space and where the operating conditions require large bearing capacity. Because of the rapid introduction of these small rollers in the automotive and industrial fields, standard sizes have not been developed and adopted. Now available in following sizes:

*0.0625 diameter x 0.625 long
0.0625 diameter x 0.656 long
0.0937 diameter x 0.484 long
*0.0937 diameter x 0.750 long
0.1250 diameter x 0.375 long
0.1250 diameter x 0.750 long
*0.1250 diameter x 0.875 long
0.1870 diameter x 1.000 long
0.1880 diameter x 0.922 long

*Proposed standard sizes.

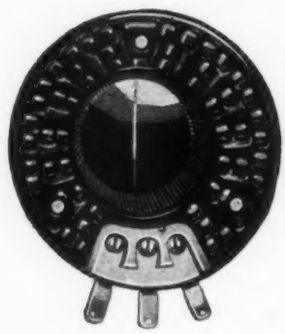
Bantam Ball Bearing Co., South Bend, Ind.



Application of Bantam rollers as anti-friction bearing for a high-speed printing press gear

Ward Leonard "Adjustat" Rheostat

With 16 steps of control provided and terminals arranged for potentiometer connection. "Dead shaft" construction completely insulated from current carrying parts simplifies single hole mounting on steel panels without use of insulating bushings. 2¾-in. circular refractory plate forms base for special resistance wire of low temperature coefficient of resistivity. Plate, wire, contacts and terminal connections thoroughly protected against corrosion and damage by fused-on vitreous enamel. Where desirable to make or break another circuit, toggle switch can be



furnished. Available in ratings from 1 to 25,000 ohms. Ward Leonard Electric Co., Mt. Vernon, N. Y.

Square D Weatherproof Circuit Breaker

In capacities up to and including 50 amp. Special box provides water-shed top and cover. One inch pipe fitting in top and knockouts in lower sides and

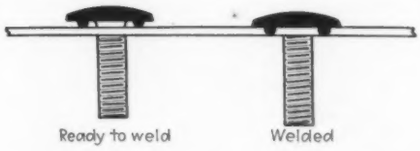
bottom permit conduit connections. Main cover slips in under water shed and can be padlocked or sealed in place. Manufactured in two- and three-pole, solid neutral, 125, 125-250 volts, and may be provided with meter test features. Square D Co., Detroit, Mich.

Ohio Capacity Type Refrigerator Motor

Does away with wound rotor, commutator, complicated brush and brush-lifting mechanism and radio interference. These motors have combination rubber cushion, spring mounting, recirculating lubrication, burnished bearings and such electrical characteristics as high torque, efficiency and power factor. The Ohio Electric Mfg. Co., 5900 Maurice Ave., Cleveland, Ohio.

Ohio Welding Bolt

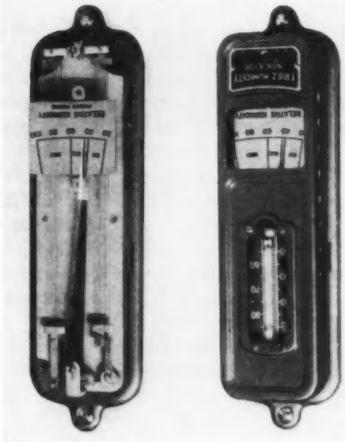
Designed to take advantage of projection welding process. As shown in illustration, the prongs or lugs on bolt-head provide for projection welding to



sheet metal using resistance welding machines. Bolts are thus welded into permanent position and cannot turn when tightening nuts. Type G1 has welding lugs on bottom of head, as shown; Type G2 has welding lugs on top of head. Latter has advantage of leaving one side of sheet clear of obstructions where flush surface is required, either for appearance or clearance. Ohio Nut & Bolt Co., 600 Front St., Berea, Ohio.

Friez Humidistat

Human hair is used for the hygroscopic element. The instrument is so equipped that it can be used with either three-wire or two-wire contacts, the contacts being so designed that either a close range or wide range of humidity can be maintained. The full range of the instrument is from 20 per cent relative humidity to saturation. By setting controller by index hand along visible scale any point of humidity throughout the range can be maintained. Julien P. Friez & Sons, Inc., Baltimore St. & Central Ave., Baltimore, Md.



"Genuine Detroit" Control Switch

Furnished in various models for the control of temperature, pressure or vacuum. Bellows element—actuated by pressure direct or by volatile liquid for temperature—operates switch mechanism to make and break circuit. Permanent magnet at contacts provides quick make and break and prevents excessive arcing. Will carry 110 or 220 volts a.c. or d.c. All models inclosed in black Bakelite case with removable cover. Detroit Lubricator Co., Trumbull, Lincoln, Marquette & Viaduct, Detroit, Mich.

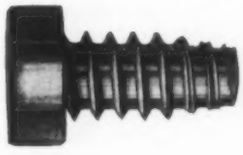
Dunco Mercury Swing-Type Relay

Wherein as far as possible the glass moves around the mercury rather than the mercury in the glass. Furnished in five standard types for controlling loads

up to 25 amp., at 110 volts a.c., or 25 amp. at 115 volts d.c., in locations where inflammable gases or vapors are present. Single-tube types mounted on base 4x4 in. Two-tube types mounted on base 5x4 in. Housing, $7\frac{7}{8}$x$5\frac{3}{4}$x$3\frac{3}{4}$ in. Struthers Dunn, Inc., 139 N. Juniper St., Philadelphia, Pa.

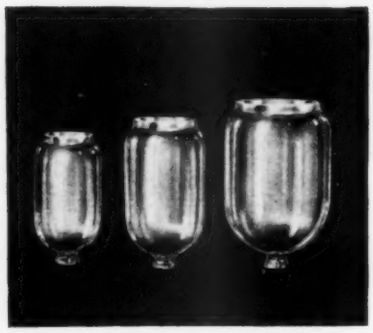
Self-Tapping Capscrews

For fastening sheet metal from 24 gage (0.025 in.) to 10 gage (0.140 in.) to steel plate or structural shapes up to $\frac{1}{2}$ in. thick, or to solid sections of brass, bronze, aluminum or other die-castings, slate, transite board, ebony asbestos, and other materials. These hex-head hardened self-tapping capscrews are available in a complete range



of sizes from No. 6 up to ½ in. diameter. They form their own thread in the material as they are being turned in, thereby eliminating tapping operations. Parker-Kalon Corporation, 200 Varick St., New York, N. Y.

Pease Thermex Arc Lamp Globes



Are blown from a special new glass of high silica content, having a minimum of expansion. Claimed to possess tremendous resistance to high and rapid changes in temperatures. To provide greater space between arc and sides of globe, and thus further to minimize melting, new shapes have been developed as illustrated. The C. F. Pease Co., 813 N. Franklin St., Chicago, Ill.

NEW BOOKS and PUBLICATIONS

"What Is Technocracy?"

Allen Raymond. 180 pages, 5x7½ inches. Published by Whittlesey House, McGraw-Hill Book Co., Inc., New York. Price $1.50.

In his effort to explain technocracy and the individuals back of it, Mr. Raymond draws on the information gained during his interviews with Messrs. Scott, Jones, Ackerman and Rautenstrauch, and which he used as the basis for four articles in the New York Herald Tribune. He also quotes from books by Thorstein Veblen and Frederick Soddy along the same lines as the technocratic preachings.

To give the arguments against the theories advanced by the technocrats he quotes Dean Kimball, John Van Deventer and President Compton of M.I.T. For those who are sufficiently interested in technocracy to want to try to find out what it is all about this book should be helpful, because it quotes sources and ties them together in a breezy, newspaper fashion that makes easy reading.

"Temperature and Humidity Measurement and Control"

M. F. Behar. 320 pages, 6x9¼ in. Clothboard covers. 278 illustrations. Published by Instruments Publishing Co., 3619 Forbes St., Pittsburgh, Pa. Price, $4.

In this one volume are incorporated Part 2 and Part 3 of the series of Manuals of Instrumentation. The present volume deals with the subjects: Thermometry, pyrometry, automatic control of temperature, and humidity measurement and control.

Under each heading the author gives the fundamental scientific basis for the operation of the instrument but it must not be assumed that the treatment of this phase of the subject is either uninteresting or difficult to understand. Indeed, the most remarkable feature of this book is the extremely interesting and simple manner in which the author clarifies the complex principles upon which the instruments operate. One is struck by the human interest that can be put into a subject usually considered dry and uninteresting.

But it must not be assumed that this is a scientific treatment of the subject. In point of space, the bulk of the book is devoted to the engineering problems concerning the design and application of temperature and humidity control and recording instruments. The chapter headings include: Indicating Thermometers, Thermo-Electric Pyrometers, Radiation and Optical Pyrometers, Temperature Recorders, Automatic Temperature Control and Temperature Control Instruments and accessories. In an appendix of about 35 pages, the author discusses thermometric lag, gives a chart and formula for the emergent-stem correction and instructions for checking pyrometers and concludes with a number of temperature and humidity tables.

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Research Bulletins

American Society for Testing Materials, 1315 Spruce St., Philadelphia, Pa. "A Study of the Embrittlement of Hot-Galvanized Structural Steel with Recommended Practice for Safeguarding Against Embrittlement of Hot-Galvanized Structural Steel Products and Procedure for Detecting Embrittlement." This is the report of an investigation sponsored by the American Society for Testing Materials at the Battelle Memorial Institute. It includes a comprehensive technical paper by Samuel Epstein and the 1932 report of the special subcommittee in charge of the investigation. For convenient reference, the Standard Specifications for Zinc (Hot-Galvanized) Coatings on Structural Steel Shapes, Plates and Bars and Their Products are included. Copies of the publication, bound in heavy paper covers, comprising 109 pages, illustrated, may be obtained from the A.S.T.M. Headquarters. Price $1.

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Air Control Valves—Q-C Engineering Products, 1310 Maple St., Detroit, Mich. Folder "'Sav-Air' Four-Way Control Valve."

Aluminum Colors—Aluminum Colors Inc., 537 E. Washington St., Indianapolis, Ind. Folder "Alumilite, A Protective and Color Coating for Aluminum."

Bronze—The American Brass Co., Waterbury, Conn. Publication B-15, second edition, "Anaconda Phosphor Bronze—Physical Properties and Applications."

Control Switches—Detroit Lubricator Co., Trumbull, Lincoln, Marquette & Viaduct, Detroit, Mich. Bulletin No. 54, "Genuine Detroit" Control Switch.

Haveg—Haveg Corp., Newark, Del. Catalog, "Haveg Corrosion-Resistant Chemical Equipment."

Motors—The Ohio Electric Mfg. Co., 5900 Maurice Ave., Cleveland, Ohio. Temporary Bulletin No. E, "Capacitor Type Refrigerator Motors."

Motorized Speed Reducers—Janette Mfg. Co., 556 W. Monroe St., Chicago, Ill. Price list RW-34-1132, "Janette Motorized Speed Reducers."

Photo-Electric Recorder — General Electric Co., Schenectady, N. Y. Bulletin GEA-1480B (supersedes GEA-1480A), "The New G-E Photo-electric Recorder."

Rubber Bearings—The B. F. Goodrich Rubber Co., Akron, Ohio. Bulletin No. 251, "Goodrich Cutless Bearings for Hydraulic Turbines."

Rubber Belting—The B. F. Goodrich Rubber Co., Akron, Ohio. Catalog supplement 2105, "Highflex Transmission Belt."

Rubber Mountings—Lord Mfg. Co., Erie, Pa. Bulletin 100, "Lord Patented Bonded Rubber Shear-Type Mountings."

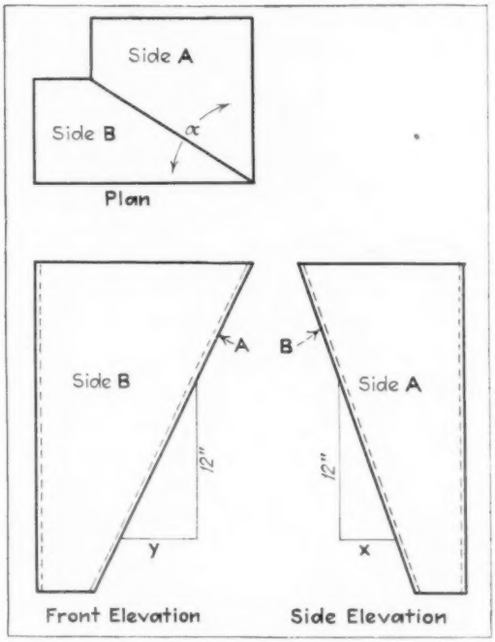
"Self-Syn" Motors—Ideal Electric & Mfg. Co., Mansfield, Ohio. Bulletin No. 540, describing full details of "Self-Syn" motors.

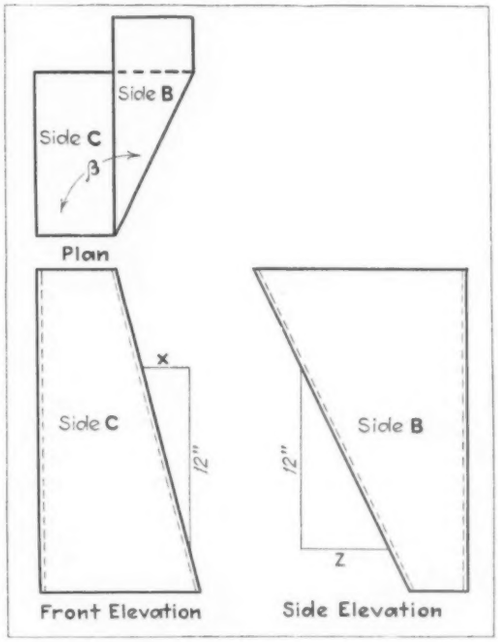
Solenoid Valves—Detroit Lubricator Co., Trumbull, Lincoln, Marquette & Viaduct, Detroit, Mich. Bulletin No. 34-C, "'Genuine Detroit' Solenoid Valves."

Thickness Measure—B. C. Ames Co., Waltham, Mass. Folder, "A New Thickness Measure by Ames."

Chart for Determining the True Angle Between Sides of Hoppers

Frequently it is necessary to determine the dihedral angle between two adjacent sloping sides of bins, hoppers, chutes, flues, and similar construction. Feeding hoppers, hopper-bottom cars, chutes for automatic machines and bins are common constructions that might require the determination of the angle between adjacent slope sheets. In order to facilitate the work of determining such angles, the chart given on the next page has been constructed. The two examples given here show how the chart is used.





Example No. 1

Let it be assumed that two adjacent sides of the hopper slope inward towards the center as shown in the plan and elevation views given above. The slope of the side *A* is 4½ in 12, and that of side *B* is 8 in 12. It is required to determine the dihedral or true angle between the sides *A* and *B*.

Referring to the dashed line given on the chart on the following page and labeled *Example No. 1*, proceed as follows: From the point 4½ on the lower horizontal scale, a vertical line is projected upward to that curve of the *Bevel of Side B* labeled $x = 8$. Projecting horizontally from this point of intersection to the left-hand vertical scale, the dihedral angle between the side sheets *A* and *B* is given as 101 deg. — 15 min.

Example No. 2

Let it be assumed that one side of the hopper sheet slopes inward towards the center and that the other side adjacent to it slopes outward from the center as shown in the above plan and elevations.

If the slope of side sheet *B* is assumed to be 5 in 12, and that of side sheet *C* is 7¼ in 12, the dihedral or true angle between the two sides can be determined from the chart.

Referring to the curve *Example No. 2* as given on the chart, from the point 7¼ on the upper horizontal scale a vertical line is projected down to the curve of *Bevel of Side B* that represents $x = 5$. Projecting horizontally to the right-hand vertical scale, the dihedral angle between the adjacent slope sheets *B* and *C* is given as 78 deg. — 30 min.

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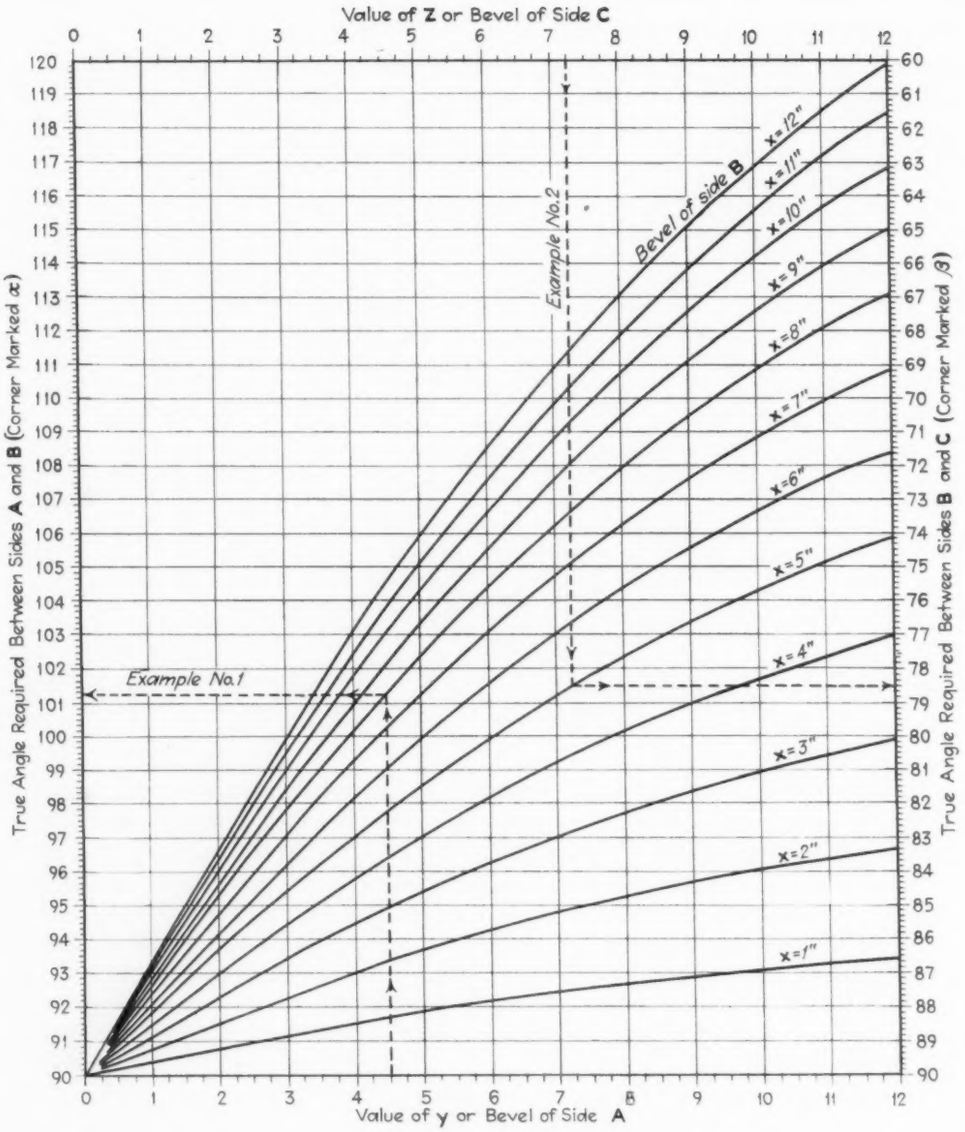
Chart for Determining the True Angle Between Sides of Hoppers


Value of Z or Bevel of Side C
0 1 2 3 4 5 6 7 8 9 10 11 12
True Angle Required Between Sides A and B (Corner Marked α)
120 119 118 117 116 115 114 113 112 111 110 109 108 107 106 105 104 103 102 101 100 99 98 97 96 95 94 93 92 91 90
True Angle Required Between Sides B and C (Corner Marked β)
60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90
Example No.1
Example No.2
Bevel of side B
x=12"
x=11"
x=10"
x=9"
x=8"
x=7"
x=6"
x=5"
x=4"
x=3"
x=2"
x=1"
Value of y or Bevel of Side A

Contributed by William J. Mackenzie
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